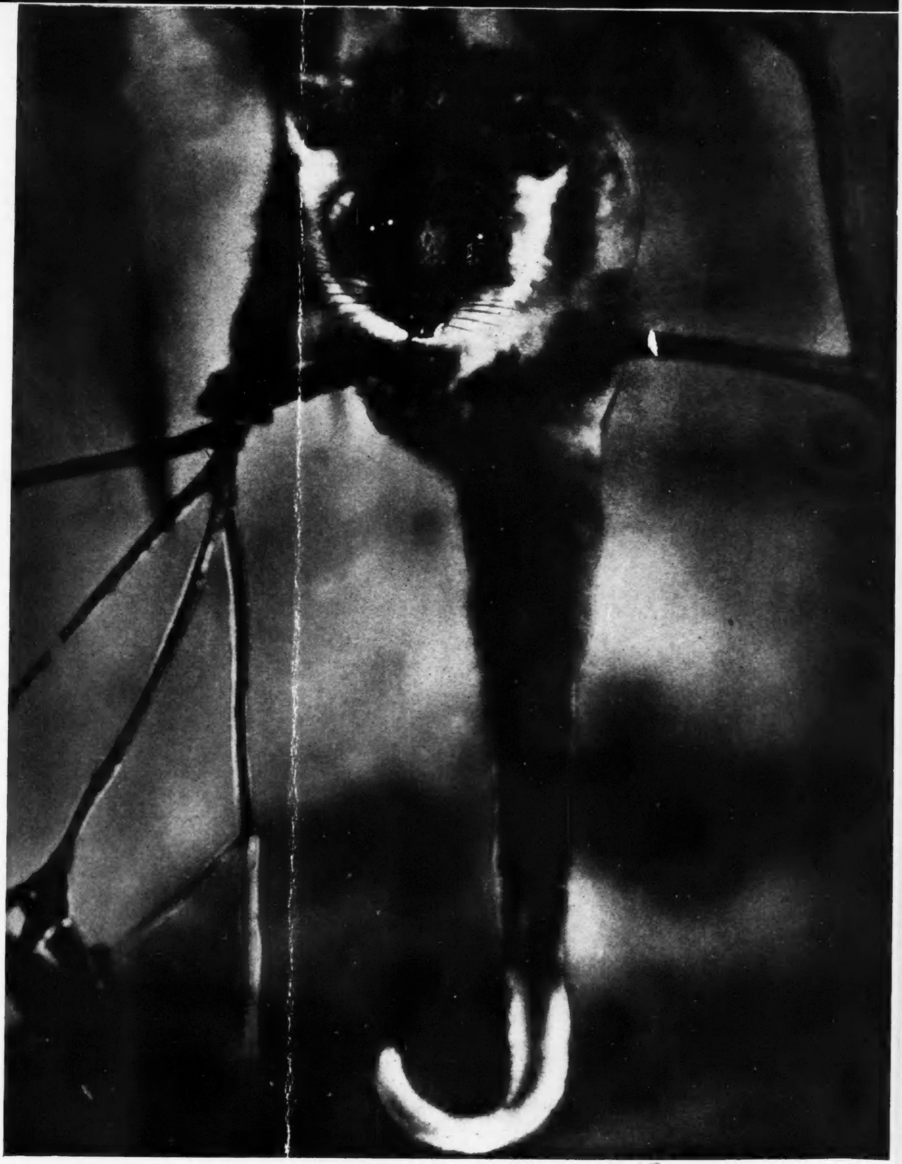
DISCOVERY



AP

Ringtail Opossum

MAY

1950

1/6

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

May, 1950 Vol. XI. No. 5

Editor WILLIAM E. DICK, B.Sc., F.L.S.
Editorial Office: 244 High Holborn, W.C.1. Tel. Chancery 6518
Advertisement Office: Temple Chambers, Temple Avenue, London, E.C.4. Tel. City 6537 (Three Lines)
All Subscriptions, Distribution and Business Communications to Jarrold & Sons Ltd., Norwich. Tel. Norwich 25261

The Progress of Science

Scientists and the H-bomb

STILL rudely shocked by the effects of the last, old-fashioned, war, it is hardly surprising that the man in the street should remain unconvinced that the hydrogen bomb is more than an unpleasant dream in the minds of a few scientists, or if he accepts the nightmare as a fact he pushes it out of his mind and thanks his lucky stars that the decision to push forward with the H-bomb project finally rested not on himself but on President Truman, so that according to his own conscience he can agree with or condemn that decision. He has been given a terrifying, sensational and doubtless distorted glimpse of the H-bomb, and to this hypothetical addition to the atomic armoury the words of Vannevar Bush (in his book *Modern Arms and Free Men*, which deserves to be read by all our readers) certainly apply: "No terror is greater than the unknown, except the terror of the half-seen." It is up to every scientist who is in a position to add something to public enlightenment on the H-bomb project to bear that point in mind. It would be in reckless disregard of his special responsibility for any scientist to do anything calculated to increase public fears about the future of atomic weapons and atomic warfare; the speech or article that is calculated only to terrify does nothing for the cause of peace, but it can betray this cause in the same way as did so much pacifist propaganda that was circulating before 1939.

It is now quite evident that immediately after President Truman's announcement of his decision on the H-bomb project most British scientists were reluctant to state publicly their views about the possible new trend in atomic armament. In the circumstances, with the politicians saying as little as possible and the experts saying nothing at all, society as a whole could not be held responsible for official policy with regard to this development, for the community as a whole was almost completely ignorant about what that policy involved. Until the public has been given enough information, responsibility in this connexion must be held to belong not to the community as a whole but to the politicians and to the experts who give the facts and technical opinions on which policy is based. In such matters the experts directly involved are precluded from contributing their full quota to public enlightenment because of the Official Secrets Acts and the special provisions of atomic energy legislation; indeed their lips are sealed with the red tape of 'security'. It is therefore more than ever up to other well-informed members of the scientific community to discharge the special responsibilities which belong to the scientists in this day and age. A start in the right direction has been made by the Atomic Scientists' Association which has devoted the whole of March (1950) issue of *Atomic Scientists' News* to a discussion of the H-bomb.

Most of the views given in that issue are individual views, but there is also an editorial for which the A.S.A. as a whole is responsible. These are the main points made in the editorial:

1. For the hydrogen bomb there is no actual size for spontaneous explosion, and hence no severe limitation upon the size of the bomb which could be manufactured, *assuming that a hydrogen bomb can be made to work at all.*
2. A bomb could be envisaged which would destroy an area of the order of a hundred square miles as compared with the 4–5 square miles destroyed by an ordinary atom bomb.
3. The hydrogen bomb would be inefficient militarily: an atomic bomb, it argues, is more than large enough for most military purposes; only in the case of huge targets, e.g. a town like London, would the hydrogen bomb's extra power do more than expend itself in open country.
4. With regard to Mr. Churchill's suggestions that the heads of the great powers should meet with the aim of breaking the deadlock over international control, the editorial maintains that no agreement would be possible until some progress had been made to overcome the fundamental causes of the clash between East and West.

Among the individual scientists who contributed to the issue are Prof. Peierls, Prof. Frisch and Sir George Thomson, all of whom played important parts in the atomic bomb project during the recent war.

Anyone who reads this symposium will naturally look for comments about any change in the prospects of finding a satisfactory solution to the problems of the international control of atomic energy and of atomic disarmament. Actually the only substantial comment on these questions

is made by Prof. Peierls, who expresses optimism over the fact that the Russians had succeeded in making an ordinary bomb, but does not really bring the hydrogen bomb into his argument, which runs as follows: "The main change would seem to be that from the point of view of the United States a scheme that would lead to inspection of declared installations without a guarantee of further safeguards would in the past have meant the loss of an important, if temporary, military advantage in disclosing to Russia details of the atom bomb project. Since Russia is now known to possess an atom bomb the advantage to them of seeing American and British installations is evidently less important, though its extent depends on our guess as to the state and efficiency of the Russian project. As time goes on a point may come when a general inspection scheme may not be of overwhelming military advantage to either side, and in that case its general advantages in restoring international contacts over a limited field might well make it worth while, even if there was no guarantee that the further steps would follow which in the past we have regarded as inseparable from this first step. I am not myself satisfied that this point has yet been reached and, in particular, it is further complicated by the hydrogen bomb. I cannot judge to what extent the hydrogen bomb involves a few important secrets which could be disclosed by such an inspection and which the Russians are not likely yet to have discovered themselves. In any case, one should bear this possibility in mind which, if it ever becomes feasible, might prove an important step away from the present trends."

The idea that something might be gained from an international convention outlawing hydrogen bombs as well as other weapons of mass destruction hardly gets a mention in the symposium. The convention on poison gas is usually brought into any argument along this line. (We note that Mr. Emrys Jones brought it up in the latest Foreign Affairs debate in Parliament on March 3.) But there is no doubt that the reasons why poison gas was not used in the last war had nothing to do with any international convention; war gases were made by both sides in tremendous quantities, and each side hesitated to start gas warfare because of the risk of retaliation on a big scale; in addition situations in which its use could have given temporary local military advantage to one side before the other could bring about retaliation in kind were rare indeed. Sir George Thomson says a good deal about this, and rightly considers that outlawing of the bomb would not necessarily prevent the bomb being made. He points out that Britain made poison gas in spite of our promise not to use it. "Similarly," says Sir George, "it would, I believe, be wrong to be the first to use the hydrogen bomb, but its possession by one side makes it much less likely to be used by the other. Further, no one ever gives their potential enemies much credit for morality and even if the United States stated that they would not be the first to use it, its existence might still be an appreciable extra deterrent to anyone planning war. It cannot be too often emphasised that wars generally arise because an aggressor sees the chance of an easy victory, or thinks he does. Weapons that make it certain that even the victor will suffer severely are a real force for peace, and to preserve peace is at present far more important than to palliate war. The possibility of making a hydrogen bomb may thus not be an unmixed evil. The arguments which justify the action of the President justify also the work of those who are called to carry out his order."

Several of the scientists demand that a halt be called to the prostitution of science to military ends. One of them, who worked on the project that gave the bombs that shattered Hiroshima and Nagasaki, says: "If I, personally, am asked to help in perfecting a super-bomb, I shall say, 'No, I am sorry, it is too disgusting'." Utter revulsion to the unlimited application of science to war purposes is expressed by Prof. Max Born, who has no doubt that the ordinary citizen is disgusted that science has been degraded to a tool in power politics. "The only remedy seems to me a violent moral reaction against the misuse of science," says Prof. Born. "Scientists should organise themselves with the aim to outlaw the prostitution of science. Though I am too old to lead, I should willingly join such a group, which might start with an attempt to formulate a code of behaviour like that valid in medicine since the days of Hippocrates. This would immensely strengthen the individual scientist in the difficult choice between his moral and religious convictions and his loyalty to the state."

As a whole this issue of the *Atomic Scientists' News* offers little in the way of ground for optimism about the future; but if it does nothing to allay fears for the future it does nothing to intensify those fears. And this issue is very welcome as a sign that the British atomic scientists face up to their social responsibilities and that the A.S.A. is still an active body, particularly in view of the rumours that have been circulating to the effect that the A.S.A. was in process of dissolution.

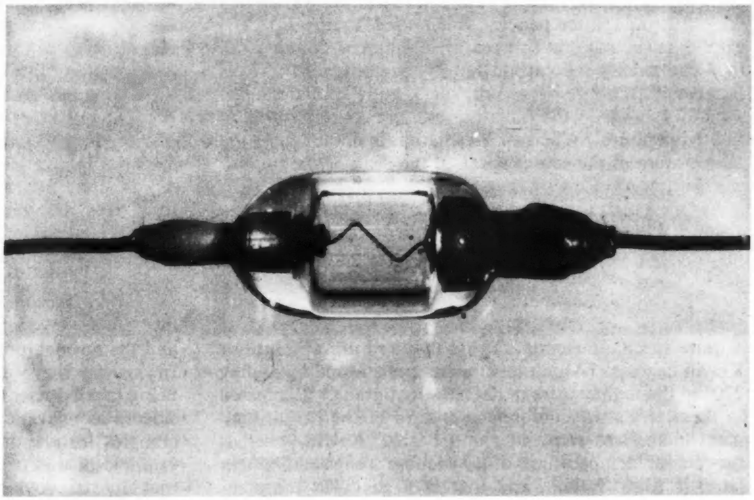
Rare Elements in Coal

THE major interest in coal for a long time to come will rest on its use as a source of energy. A further large field of interest lies in its use as a rich source of chemicals ranging from complex dyes to sulphate of ammonia. Now comes a new approach to this rich mineral—coal as a source of rare elements.

Germanium, for example, is now being produced commercially in Britain from the dust left behind in the flues of industrial coal-burning installations. This element was first discovered in 1886 in the mineral argyrodite. The German chemist, Winkler, on analysing a specimen of mineral, was unable to make his results total correctly, and the source of the discrepancy proved to be this new element. Supplies of the mineral, which is a double sulphide of germanium and silver, are now exhausted. Then about twenty years ago another German chemist, Goldschmidt, working at Göttingen, found this element to be present in coal. He was examining a number of German coals for trace elements and obtained from the local museum collection a 70-year-old sample of English coal so that he could compare it with the other samples. By an extraordinary chance this English sample gave an ash with the phenomenally high concentration of 1·1% of germanium; many coal samples have since been analysed, but no sample richer in germanium has been obtained.

During the burning of coal, the germanium tends to go into the gases rather than staying in the ash. Because of this volatility of germanium, a relatively rich source is boiler flues dust. This dust consists of small particles of solid which settle out in boiler plant along the flues,

particularly where the hot flue gases change direction. It includes some ordinary ash which has been mechanically lifted and carried due to the speed of the draught, but it has a generally different composition from ordinary ash because it also has more of the volatile constituents. Among these is germanium, in which the major valve firms are interested because of the element's electrical rectifying action. If an alternating current is applied to a germanium crystal under appropriate conditions, the current can pass only in one direction and is blocked in the other direction. This is the principle of all crystal detectors. In Britain germanium valves are manufactured by the General Electric Co. who rely on Johnson Matthey and Co. Ltd.



The modern cat's whisker or germanium crystal diode: the wire whisker makes contact with the germanium on left. (*G.E.C. photo.*)

Another of the elements which has been extracted from coal, called gallium, remains for the moment a scientific curiosity, without any application. It has one outstanding and unique property: along one crystal axis its electrical resistance is no less than seven times that along an axis at right angles. This element is also volatile and tends to go into the flue dust rather than the ash. One exceptional coal sample has been found with 1·58%, but more usual figures are 0·04–0·55% of gallium in dusts from coals of the Northumberland and Durham coalfields. As the name indicates, it was discovered by a Frenchman, Lecoq de Boisbaudran. His source was a sample of zinc blende from the Pyrenees. Gallium is among the scarcest of elements and knowledge of its properties is only now being appreciably built up by work at the Chemical Research Laboratory, Teddington. Here, flue dusts have been treated by fusion of 10 kilogram lots with caustic soda, and working up the water extract from the melt. Over five hundred grams of this rare metal have now been recovered at Teddington.

It has another very interesting property. Next to mercury, it is the metal with the lowest melting point—30° C., as against—38° C. for mercury. This means that it will readily melt if surrounded by warm water; on a really hot day the metal will become liquid, for the melting point corresponds with 86° F.

Many other 'minor' elements have been detected and investigated in coal. Arsenic, for example, which is of particular significance when it occurs in samples of anthracite used in the malting industry. Here the hot gases from the coal are directly passed over the malt; since the arsenic is often in volatile form, the significance is obvious and a limit in arsenic content is part of the specification for coal for this purpose.

The Candela

The National Physical Laboratory has been using a new unit of luminous intensity since January 1948, but only recently has this unit received a name, the *candela*. Its establishment is part of the history of science, and indicates the advances made in photometry in the past century.

From the beginning the fundamental unit was a purely empirical one, and there has always been difficulty in establishing a practical standard that could be reliably reproduced from a written specification. At first the spermaceti candle of certain dimensions and rate of burning was the standard, giving us the expression 'candle-power'. This was legalised under the Metropolitan Gas Act of 1860, but proved so unsatisfactory that it was discarded in 1898 and replaced in Great Britain by the Harcourt pentane lamp, in which air saturated with pentane vapour was consumed in a special burner to give a flame with a luminous intensity equivalent to 10 candles. In France the Carcel lamp, burning colza oil, was used, and in Germany the Hefner lamp, burning amyl acetate.

All these flame standards were also unsatisfactory, for they were not reliable over a period of time; moreover, only a highly skilled operator could reproduce the standard, and even then he had to have luck. As early as 1902 Fleming suggested electric filament lamps as practical standards. Comparisons of carbon-filament lamps were carried out at the N.P.L. and at other national standardising laboratories in 1909. Considerable differences were found to exist between the units of candle power being used in the U.S.A., France, and Great Britain, and they all agreed to use thenceforth the one obtaining here. A steady exchange of lamps between the standard laboratories of the three countries was kept up and so a reliable secondary standard was maintained. In 1921 the unit was called the 'international' candle. Germany continued to use the Hefner candle.

The lamps were not primary standards; they were secondary. In addition they took no account of differences in the colour of a light source. In 1924 the Commission Internationale d'Éclairage agreed to a luminosity curve for a 'standard' observer, a curve showing how the average observer varied in sensitivity according to the colour of the

light. When this was taken into consideration, the carbon lamps showed discrepancies when used to measure the candle-power of light-sources of a different colour from that emitted by the carbon lamps themselves. This was because such lamps were not 'black-body' radiators, i.e. radiators in which the radiation emitted depends only on the temperature. When such radiation is obtained, as the temperature of the source is raised the peak of the smooth curve showing the distribution of radiation through the spectrum moves towards the region of shorter wavelength. In other words the light gets less red and more blue. Because of this, the colour of a 'white' source can be expressed in terms of the temperature to which the black-body radiator must be raised to give the colour observed. This temperature is called the 'colour temperature', which has therefore a quite specific meaning. The units used are absolute or Kelvin degrees. (Absolute temperature is found by adding 270° to the temperature in degrees Centigrade.) Expressed in these terms the colour temperature of the carbon-filament lamps was something under 2000° Kelvin, whereas the colour temperature of a vacuum tungsten-filament lamp is 2360° Kelvin, and that of a gas-filled tungsten-filament lamp is 2800° Kelvin. Quite clearly, for commercial purposes a standard is required that will be accurate in terms of such lamps.

As early as 1899 Violle suggested platinum at its melting point as a primary standard. This has now been taken up again, and in 1946 the International Committee of Weights and Measures agreed a new primary source. This consists of a small tube of thoria immersed in pure platinum. This is melted and allowed to cool. As it solidifies its temperature remains constant for some time. The brightness, or luminance, of the mouth of the tube is measured at this time and used as the primary standard. The colour temperature is 2046° Kelvin, sufficiently near that of the carbon-filament lamp to be used for direct comparison. In terms of the international candle the luminance of this source was found to be 58·9 candles per square centimetre. It was decided to alter this awkward figure and call it 60 'new' candles. To this new unit the name *candela* has now been given. The primary source, being a full radiator, can be used in conjunction with the standard observer's luminosity curve to measure light sources at other colour temperatures. Thus a logically sound primary standard is established and is likely to remain in photometry for a long time.

An Operational Research Journal

THE literature of Operational Research—which has been well defined as "a scientific method for providing executives with a quantitative basis for decisions"—consists largely of confidential reports circulating only in military circles. It is important that operational research techniques with their great peace-time possibilities should be widely understood and applied; to this end open discussion and publication on the subject is needed. For this reason we welcomed the formation of Britain's Operational Research Club, and now we are pleased to report that this Club has started a journal, *Operational Research Quarterly*.

The first number contains an article by Professor P. M. S. Blackett, who was the outstanding figure in the operational research field during the last war. This article is full of good sound sense and helps to clear away some of the air of mystery which has hung around the subject. The mystery was mainly caused by necessary secrecy with regard to operational research results, but some of it derived from the way some of the operational research workers indulged in pretentious talk about their techniques. Professor Blackett stresses that to make statistical analyses of everything that is happening in the hope that some of the statistics may somehow and sometime prove useful is no more operational research than collecting beetles is biology. He recommends the war-time system whereby the operational research group works in close personal contact with the executives. During the war the operational research men watched decisions being made; they attended the regular staff meetings at operational headquarters, and learned the type of problem facing the executive officers and the normal methods by which decisions were reached. In this way they were enabled to spot problems capable of being tackled scientifically, which had either not been considered as relevant problems, or had been held to be too complex for scientific analysis. Prof. Blackett quotes one example of this from the anti-submarine war. The proof that large convoys were safer than small ones arose from an investigation into the protective value of convoy escorts. This analysis was undertaken as a result of an operational research worker being present at a meeting of the Anti-U-boat Committee at 10, Downing Street, when the problem arose as to how best to divide our limited ship-building resources between merchant ships and escort vessels.

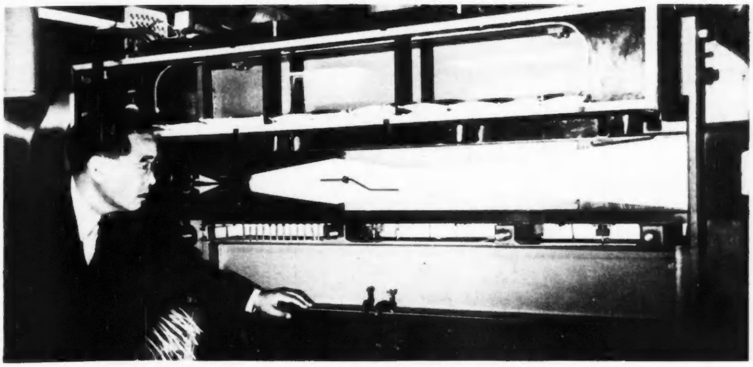
"Though it is, in my view, essential for the greatest efficiency that senior operational research workers should be admitted to the executive levels as observers and potential critics, and, whenever possible, should have close personal relationships with the executive—the situation during the war when they often shared the same mess was ideal—they should never, in general, have executive authority." Professor Blackett continues, "If they had, they would soon get so involved in detail as to cease to be useful as research workers."

The rest of the article is so much to the point that it deserves full quotation.

"Conversely, though the research workers should not have executive authority, they will certainly achieve more success if they act in relation to the conclusions of their analysis as if they had it. I mean by this that when an operational research worker comes to some conclusion that affects executive action, he should only recommend to the executives that the action should be taken if he himself is convinced that he would take the action, were he the executive authority. It is useless to bother a busy executive with a learned resumé of all possible courses of action and with the conclusion that it is not possible to decide between them. Silence here is better than academic doubt. Research workers must also guard against the temptation to expect the executive machine to stop while they think. War, manufacture, trade, government business—all must go on, whether the research worker is there or not.

"It is not possible to lay down rigid rules about the qualifications required in an operational research worker. As has been said, operational research is scientific, and training in some scientific discipline may be regarded as essential, although it need not necessarily be in the exact sciences. The most important qualification is ability to take a broad view of a problem, so that important factors

will not be missed. Some knowledge of statistical methods will be required, at least within an operational research group, even if not in every worker in the group. Specialist knowledge (technical, industrial, economic, or social) appropriate to the field of application is desirable, but is usually acquired on the job. A high degree of general intelligence and enthusiasm for the work are important. Above all, the right personality is vital, so that during an investigation the operational research worker can obtain the confidence of the men on the job, and at the end, can put his conclusions across to the executive. I want here to state specifically that I entirely repudiate the notion that operational research scientists are necessarily in any sense more intelligent or clever than the executives. They are usually not, but they are differently trained and are doing a different job."



Speeds in excess of Mach 10 are attained in the hypersonic wind tunnel of the California Institute of Technology.

As many of our readers will doubtless wish to subscribe to *Operational Research Quarterly*, we give the address of the journal's business office, which is 25, Buckingham Gate, London, S.W.1.

A Wind Tunnel for Studying Rockets

THE problems of flight at supersonic speeds are very different from those at the comparatively low speeds at which we fly today. Similarly, the experimental apparatus required for their investigation, while basically being the same for both, differs in actual practice. This apparatus is the wind tunnel, in which a model of the full-size body is mounted in a stream of air and the forces and pressures arising on the model can then be investigated.

A low-speed tunnel in essence is just a duct with a large fan installed in it, the rotation of the fan causing the air to circulate. Except for one or two exceptional cases, the working section where the model is placed is at atmospheric pressure.

When it comes to obtaining a supersonic stream, this system of circulating the air is no longer possible and, in addition, the pressure in the working section of the tunnel must be considerably reduced in order to reduce the density of the air; otherwise colossal power would be required to produce the high air-speeds.

Fundamentally, a supersonic tunnel consists of a reservoir in which the air is at high pressure, and the high-speed jet of air is obtained by letting this high-pressure air expand through a suitably shaped nozzle. Thus, as the pressure and density of the air falls, its speed increases until the desired velocity is reached. The idea is not a complicated one, but to implement it in practice proves an extremely difficult and expensive matter.

One of the main problems is the provision of a continuous supply of air at high pressure. This means using a very large compressor or a number of smaller ones working in series, to feed the air into a large vessel capable of withstanding the pressure. The design and construction of the nozzle presents both a complex theoretical and a difficult manufacturing problem. Once the shape has been calculated, the nozzle has to be machined from solid metal, since this is the only satisfactory method of obtaining a true profile. The deceleration of the supersonic stream to conditions suitable for re-entry to the compressors is not a simple matter, in that it is accompanied by the formation of shock waves across the tunnel.

A further difficulty arises from the temperature drop associated with the expansion of the air, and special arrangements have to be made to meet this.

The humidity of the air can cause trouble so the air which circulates in the tunnel must be thoroughly dried before use, otherwise the temperature drop in the working section will cause a fog to form, or bring about a phenomenon known as condensation shock (in which the water vapour comes out of suspension in an abrupt manner). Condensation of the moisture in the laboratory air on the outside of the working section's glass walls, which are cold, must also be guarded against; otherwise schlieren photography, which enables the pattern of air flow round the model, cannot be used. (Changes in air density are accompanied by changes in its refractive index, and these latter changes are recorded by schlieren photography.)

The attainment of an air speed ten times that of the speed of sound in the new supersonic tunnel at the California Institute of Technology can, therefore, be appreciated as a remarkable achievement. Nine hundred horse-power is required to drive the fifteen compressors which compress the air into a tank 3 ft. in diameter and 12 ft. long, the walls of which vary from $1\frac{1}{2}$ to $2\frac{1}{2}$ in. thickness. The air accelerates through a throat in the nozzle which is only six-thousandths of an inch wide. To accelerate it to a Mach number of 10 the nozzle then diverges until in the working section it is 5 in. square. In the working section the pressure is about 1 millimetre of mercury, or a thousandth of normal atmospheric pressure, and the temperature drops to 430° F. below zero. The difficulty of moisture condensation on the outside walls is overcome by having double windows with a special drying material between them. Removal of moisture from the working air inside the tunnel is sufficient to allow from 10 to 20 hours running without re-drying. This tunnel, which is the first in the world to operate continuously at such a high Mach number is to be used mainly for the investigation of air flow past rockets and guided missiles.

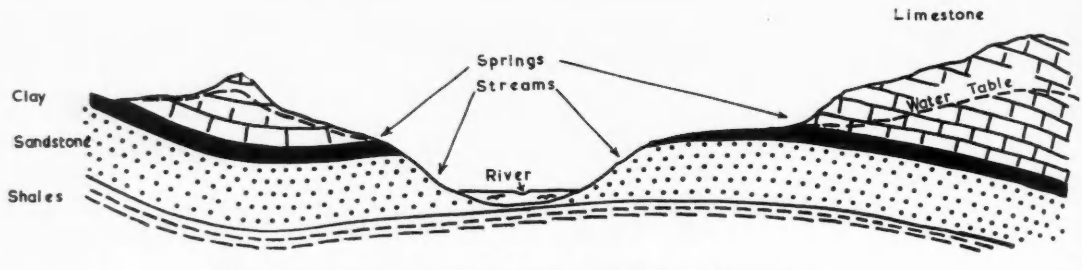


Fig. 1.—Diagram showing variation in the water table due to impermeable rocks.

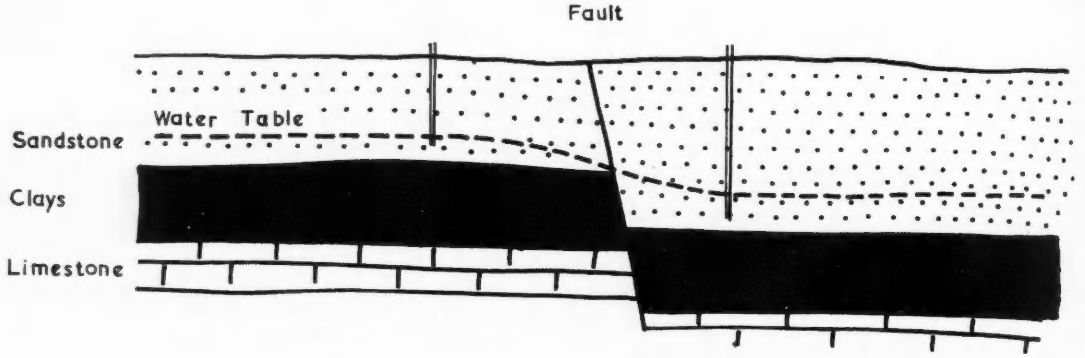


Fig. 2.—Local variation in the water table due to faulting of an impermeable rock.

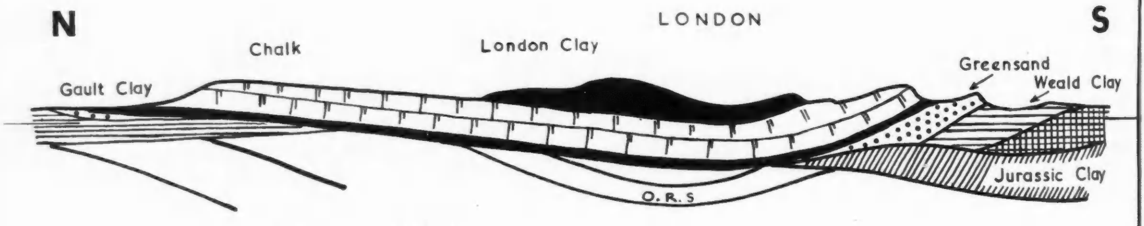


Fig. 3.—Generalised north-to-south section across the London Basin. The main water-bearing rock, the chalk, occurs between two impermeable formations, the gault and the London clay, to yield water under artesian head in the centre of the section. (After Buchan.)

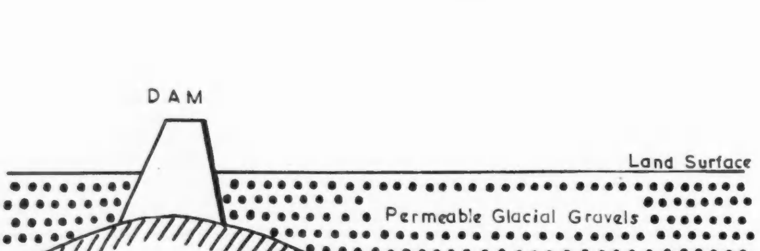


Fig. 4.—Diagrammatic longitudinal section through the Lake Vyrnwy reservoir, showing the lip of impermeable rock chosen for the dam site.

Br

THE loca
was main
their sub
to the po
tance of
attention
isolation
and sewe
a supply
filtration
and whicl
the rapid
the last t
water, an
public wa
homes pu
year sees
water to

In the s
and rainfa
obvious to
and reser
water as
undergrou
through 1
tion of 56
from unc
remainder

1949 w
hot summ
by persist
was well
characteri
low-pressu
shores.
meteorolo
which spr
during the
and deep
bringing g
parts of t
the slow-r
and gentle
and factor

It is a
Wales, the
western se
high. In
older geo
derived fro
An examp
associated
to the den
industrial
ironic tha
trated on t
never a pr

A large

Britain's Hidden Water Supplies

F. A. HENSON, B.Sc., F.G.S.

THE location of many early villages and towns in Britain was mainly determined by the availability of surface water; their subsequent growth and development frequently led to the pollution of the water supply. Once the vital importance of disease-free water was realised, then increasing attention was paid to purifying domestic water and the isolation of sources of supply from pollution by animal and sewer refuse. Wells were sunk, and these provided a supply of water which had been cleaned by natural filtration through porous rocks such as sand and chalk, and which maintained its purity throughout the year. With the rapid growth of industry and of the population during the last two centuries came the need for more and more water, and this brought about the establishment of large public water undertakings. Today in millions of British homes pure running water is always on tap, while every year sees an extension of the intricate network supplying water to farms and cottages.

In the summer of 1949, the fact that our water supplies and rainfall are intimately connected was made more than obvious to everyone, but despite the very low level of rivers and reservoirs comparatively few people were left without water as a great proportion of our supplies comes from underground reserves, which, though depleted, saw us through last summer. Thus, of London's daily consumption of 568 million gallons, 275 million gallons are pumped from underground sources of the London Basin; the remainder is taken from the rivers Thames, Lea and Stour.

1949 was an abnormal year; during the exceptionally hot summer the weather in this country was dominated by persistent anticyclones, and as a result the total rainfall was well below average. Fortunately in normal years the characteristic feature of our weather is the procession of low-pressure areas which move across the Atlantic to our shores. A feature of these low-pressure areas—the meteorologist's 'depressions'—is the rain and cloud belts which spread across the country from the west. Thus during the first weeks of February 1950 a series of vigorous and deep depressions moved rapidly across this country, bringing gales, heavy rain and eventually floods to many parts of the country. It is such depressions, particularly the slow-moving ones, which give rise to sustained drizzle and gentle rain that provide the water we use in our homes and factories.

It is a well-known fact that in mountainous areas of Wales, the Lake District, the Pennines, Scotland and our western seaboard generally, the average annual rainfall is high. In many of these areas, which are formed of our older geological formations, most water supplies are derived from springs, streams, lakes and impounded waters. An example of the last mentioned is Lake Vyrnwy and its associated reservoirs, the size of which bears no relation to the density of population in that area, but to the distant industrial centres of the Midlands which they supply. (It is ironic that the greater part of our population is concentrated on the lowlands, but areas where water supplies are never a problem are thinly populated.)

A large proportion of the rain that falls on Britain slowly finds its way back to the sea by surface drainage, by ditch, stream and river; this is known as 'run-off'. Since Roman times the rate of this movement has increased considerably, mainly due to deforestation, improved drainage and the increased area of land under cultivation.

However, despite a further loss by evaporation and plant absorption, 20–30% of the total rainfall percolates downward through the soil into the rocks below. The subsequent history of this fraction of the rainfall is mainly determined by the physical properties of the rock, the geological structure and the elevation of the area. Most rocks, particularly those of sedimentary origin (e.g. sandstones and chalk), were laid down as bedded deposits. Such rocks contain innumerable pores into which the ground waters seep. Where these pores are large and continuous they become quickly filled with water, which then uses these pores as channels to move through the rock. A rock which is both porous and permits the free movement of water is known as an *aquifer*. If, however, the pores are small, then surface tension prevents, or very much retards, such movement and the rock, although porous, is for all practical purposes impermeable; as an example, dry clay will absorb up to 30% of its own volume of water, but once the minute pores are filled with water the clay becomes impermeable and a complete barrier to water movement.

Equally important is the fact that when clays are saturated with water they become plastic. No system of joints or cracks can thus develop in such strata to assist the movement of underground water; consequently they are poor aquifers. Such impermeable deposits can, however, play an important, if negative part, in the accumulation of underground water because they provide barriers to descending ground water. Figs. 1–3 show how these impermeable rocks form deep-seated 'floors' and 'dams' to underground reservoirs.

Crystalline granites, like compact limestones, are rocks of very low porosity, yet they can be good aquifers. Thus, the granites of Devon and Cornwall are the principal aquifers of the West Country, as the waters conserved in the joint systems of the granites, which outcrop in the moors, provide spring-waters to valleys which can be impounded for overground supplies. The supplies for Redruth, some 160,000 gallons daily, are drawn from a disused mine shaft in the granite, whilst at Gwinear the available daily yield is twice this amount. Fig. 6 shows the texture of a typical granite, composed of quartz, felspar and minor constituents. Such igneous rocks, in contrast to those of sedimentary origin, result from the crystallisation of molten rock; they have a characteristically low porosity, and some of them are highly impermeable. On the other hand, many of these dense crystalline rocks are highly permeable as they are traversed by cracks produced by contraction during cooling and others developed by earth movements upon such massive rocks.

It will now be realised that the association of permeable rocks such as sandstone with an impermeable rock such as clay can provide a natural reservoir holding water that can be tapped for domestic and industrial supply. When

possible, artificial reservoirs are sited so as to take advantage of the association of these two kinds of rock. The site will not be ideal for reservoir construction unless the valley or depression to be used for impounding waters is floored by impermeable rocks. Consequently the first step in reservoir construction is geological survey. In the past several big projects were imperilled by the omission of this essential preliminary. As an example, over £400,000 was spent on the reservoir in Silent Valley (Co. Down) before the faults of the site were realised. Borings had been made in the valley, which made it appear that the permeable glacial deposits were fifty feet thick. Large boulders of granite were met at that depth, and they were considered to represent the impermeable valley floor. This was a mistake, as was recognised later; but not until construction was well advanced was it realised that the true thickness of the permeable deposits was nearly 180 feet. This meant that 180, and not 50, feet of gravels and sands had to be removed to reach a watertight foundation. The difficulties were overcome, however, and the reservoir now stands as a triumph of engineering skill.

By contrast, the siting of the dam of the Vyrnwy reservoir was much more successful. A detailed geological survey was made, and the depth of solid and impermeable rock from the surface was accurately determined by a series of over two hundred borings. As in the case of the Silent Valley, permeable glacial deposits covered the impermeable valley floor. This site was recognised by the geologist as an old lake scooped out by ice during the glacial periods. In Fig. 4 the layer of solid rock which holds back the water in this basin is shown diagrammatically, and this natural barrier the geologist was able to locate, so enabling the engineers to use it as the foundation of the dam. It has been estimated that the choice of a site two hundred yards above or below the present site would have added another quarter of a million pounds at least to the cost of this project, because of the expense of excavation to reach solid rock.

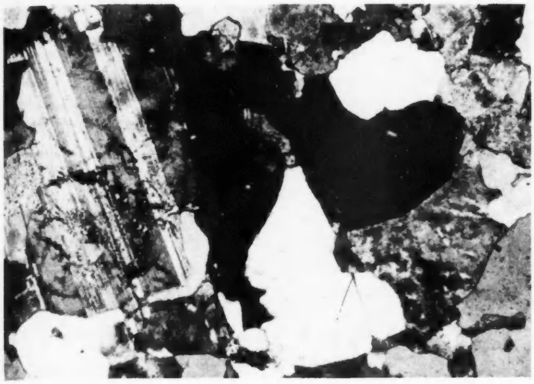
FIG. 5.—Artesian overflow 25 ft. above the surface. This picture was taken of the Spalding U.D.C. boring at Bourne in 1946.
(*Courtesy, C. Isler & Co. Ltd.*)

The degree to which any rock formation becomes saturated with water depends to a large extent upon its permeability and porosity. Only a small percentage of the total rainfall finally seeps through the rocks to the level of saturation. This level, which is known as the water table, varies from place to place although it quietly reflects the topography of an area. Its position is controlled by the ratio of water percolating into the ground to that lost by seepage from springs or extraction from wells and boreholes. Where excessive pumping of water from boreholes has taken place the water table may show a progressive fall over a period of years, as has happened in the case of London in the last sixty years.

The water table shows a seasonal variation according to the amount of rain that falls. So the water table in many parts of this country was still low long after the 1949 drought ended, and it was only with the spring rains of 1950 that it rose in some parts to a nearly normal level. Throughout the area of England to the south-east of a line from Hull to Exmouth, the principal water supplies are taken from wells and boreholes which reach to the water table. When the wells run dry, as they did in 1949, it was because the water table had fallen below the bottom of the wells, and further supplies of water could only be obtained by deepening the wells.

In permeable rocks like the Bunter sandstones of the Midlands (Fig. 7), any abnormal increase in the rainfall is reflected in a general and fairly uniform rise of the water table throughout the formation. In the chalk, however, percolation is relatively slow, except in areas where fissures and fractures assist this movement. The result is that abnormally heavy rainfall may cause the water table in the chalk to rise by as much as 20 to 50 feet in zones where it is very fissured, though the rise may be very slight generally elsewhere. This accounts for the great variation in the level of wells in the fissured chalk during wet seasons. During dry summer months, the water table falls appreciably; an annual rise and fall of water-level is characteristic of wells in the Chilterns and other chalk areas. Here the mean annual rainfall over several years is of greater importance than the rainfall for any particular year. At the present time the general tendency is for the water table in such areas to fall.

In some areas, although the rocks at the surface are permeable and abundantly fissured, the downward movement of percolating ground waters is arrested at comparatively shallow depth by impermeable strata such as clay or marl. Under such conditions a natural reservoir of water is formed very near to the surface. This results in a local restriction of water near to the surface, which is known as a *perched water table*. An interesting case occurred at Cottingham, near Hull, where five million gallons of water a day are pumped from the chalk at a



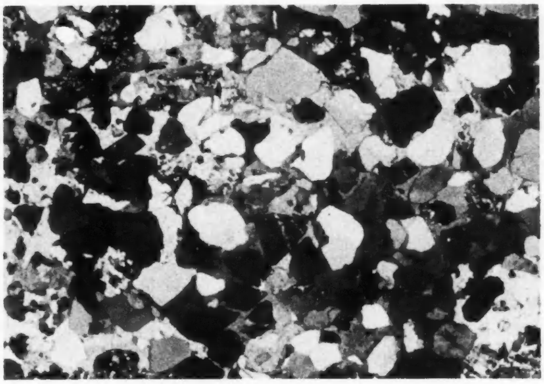
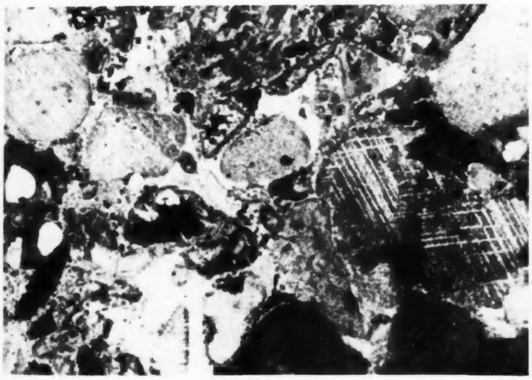


FIG. 6 (*left*).—Granite as the geologist sees it with the aid of a petrological microscope. The constituent minerals (quartz, felspar and biotite) interlock with the result that there is no development of pores. Where the minerals are fractured due to movement, some water may percolate through the rock (Granite, Noirmont, Jersey, C.I. × Nicols). FIG. 7 (*right*).—In contrast to the compact crystalline granite this rock, Bunter Sandstone, is formed of sub-angular to rounded grains of quartz and other minerals. In such a rock water can move freely through the interstices between these grains (Bunter Sandstone, Bramcote, Notts. × Nicols 16 ×).



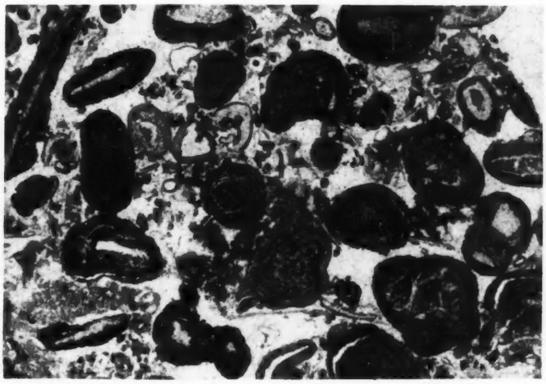


FIG. 8*a* (*left*).—Compact crystalline limestone containing calcite ($CaCO_3$, striated appearance), quartz grains and shell fragments. Such limestones are initially of low porosity, but the calcite may be removed by percolating groundwaters, making the rock permeable (Carboniferous Limestone, Llangollen). FIG. 8*b* (*right*).—Oolitic limestones, formed of rounded grains of calcium carbonate loosely cemented together, are extremely porous and permeable due to the large numbers of well-developed pores between the ooliths (Malvern).

depth of 84 feet. Below the chalk a thin band of impermeable marl occurs, and trial excavations showed the chalk below this marl to be dry. Experience showed that the water held by the upper chalk, from which normal supplies were taken, quickly disappeared into the excavations in the chalk below the marl. Thus the direct result of increasing the depth of the borehole was to jeopardise supplies already tapped. Many cases of such perched water tables occur, and in such cases extreme care has to be taken when boring; one may lose a good source of water in the attempt to find deeper and more abundant water supplies.

In the Midlands the Bunter sandstones provide abundant supplies of relatively soft water. These sandstones are overlain in many areas by the impermeable Keuper Marl. In Nottinghamshire these rocks slope gently to the east, and the marl forms a watertight cover over the water-saturated rocks below; consequently the depth of the water table increases as one goes eastwards. Under such conditions hydrostatic pressure will force the water up from the sandstone through boreholes in the marl, and this water is said to be under 'artesian' head (see Fig. 5).

In limestone areas, such as the Peaks of Derbyshire, the Pennines and the Mendips, the drainage systems frequently present many interesting and picturesque features, such as underground rivers and pot-holes. These features are caused by the association of soft soluble limestones with insoluble impermeable rocks. (Photomicrographs of limestone are seen in Fig. 8.) In rolling chalk country of eastern and southern England, the effects of solution are less striking at first sight than in the older limestone areas. Nevertheless, the dry valleys, swallow-holes, underground streams, as well as the seasonal streams known as 'bournes'

FIG. 9.—Various types of boring tools used in the construction of deep boreholes. (*Courtesy, C. Isler & Co. Ltd.*)

FIG. 10.—A group of 18-in. cores, Derby. Such records are of great importance to the geologist, whether the borehole is put down in search of water, oil or coal. The rocks in this illustration are Keuper Marl (veined with white gypsum) and sandstone. (*Courtesy, C. Isler & Co. Ltd.*)

are indicative of the solvent action of rainwater on chalk. Normally, chalk is very porous and will hold up to 40% of its volume of water, but in parts it is of low porosity. Fortunately, however, the chalk is well fissured, and as a result it usually contains considerable quantities of water, which can be tapped by wells and boreholes.

Many interesting variations occur in the general water-yielding powers of chalk deposits. Whilst in general all chalk areas will provide some underground supplies of water, there are many anomalies caused by geological phenomena. For example, as a result of folding in the chalk of the Epsom Downs, boreholes put down at Epsom and nearby Fetcham provided good yields. At Ashtead, which lies between these two places, the supply was poor in contrast. This was due to the presence of upfolds or anticlines in the chalk at these two localities and a complementary downfold, or syncline at Ashtead. Waters accumulated readily in the outwardly radiating fissure systems developed in the crest of the anticlines, whilst the compact core of the syncline inhibited the flow of water.

In many areas loose superficial deposits such as sands, river gravels, boulder clays and peat may mask the solid geology. They vary in age from the recent alluvial deposits of the present rivers to the boulder clays and gravels of the glacial periods. These alluvial deposits are mainly composed of fine clays and silts, whose very nature prohibits the percolation of water.

The older river gravels laid down since the glacial period are comparatively shallow and restricted. They are formed of rounded water-worn pebbles and water passes freely through them. From shallow wells of such deposits (particularly in the case of the Ouse in Huntingdonshire where impervious clays underlie the gravels) considerable quantities of naturally filtered water are obtained. In heavily populated areas contamination of such supplies is always a danger, and emphasises the present need for preventing the pollution of lowland rivers. In the Fens, where the post-glacial deposits are mainly formed of peat, clays, silts and some thin sand and gravel seams, little water suitable for domestic use is available.

Britain's glacial sands and gravels contain relatively large quantities of underground water. Wells at comparatively shallow depth in such deposits have high daily yields. In areas where these sands and gravels are exposed at the surface, there is a high risk of the water being polluted.

The relationship which exists between the distribution of gravels and settlements is clearly demonstrated in the neighbourhood of Oxford, where villages occur on valley gravels in the Thames flood plain. In many parts of Norfolk, Suffolk and Essex, many villages and small towns came into existence because of the availability of water in the glacial sands and gravels.

The story of London's water supplies may be very briefly summarised as a case where demand has outrun supply. With the rapid growth of population, and more recently the development of industries in the area, more and more boreholes were sunk by factories, hotels and public water undertakings into the water-saturated chalk beneath the impermeable cover of the blue London clay. Originally, when the chalk was reached by boring through this impervious cover (see Fig. 3) the water emerged under great hydrostatic pressure and rose of its own accord to levels well above the surface. Such conditions unfortunately were not allowed to persist. The water table has now been so lowered that in the Thames Estuary the sea-water began to seep into the chalk to take the place of the receding fresh water drawn off by the wells and boreholes of the London area. This became so serious that strict controls had to be imposed as, once in, the saline waters can never be expelled.

Over half of the water consumed by London today is taken from the rivers, but in times of drought it is necessary both to watch and carefully control the flow of water over Teddington Weir, for river water is essential to cleanse the estuary.

At the present time Greater London has a desperate need for more water, and the demand is increasing. Obviously more water cannot be obtained from underground sources in the area; indeed, it may be necessary to restrict even further the amount of water that is taken from the chalk. By impounding surface water outside the

Greater London area and constructing supplementary reservoirs further supplies could be made available. The Enbourne Valley scheme is a case in point, although this has been temporarily shelved. One day London may have to import water from the Welsh mountains!

Another solution to the problem may lie in the transfer of industry and population to new satellite towns, which should obviously be sited where water supplies are adequate for both present and future needs.

The Search for Water

The demand for water is on the increase, and in helping to meet this demand the geologist, water engineer and the chemist are all actively engaged. The geologist has to locate the water, the engineer makes the water available, whilst the chemist maintains its purity.

In assessing the potentialities of water supply from underground sources in an area, the geologist requires a complete knowledge of the topography and distribution of permeable and impermeable rocks in the area. This assumes, of course, that the rainfall is sufficient to permit some water to percolate underground and that catchment areas of permeable rocks occur at the surface over sufficiently large areas. The problem then resolves itself into tracing underground the distribution of these water-bearing rocks, and assessing the amount of water available in the natural reservoirs within the rocks (Figs. 9, 10). Complications, due to folding, faulting (see Fig. 2), and thinning out of both impermeable and permeable rocks, may arise. However, the geologist is able to use the information about rock structure provided by existing wells, and can explore the rock structure further by geophysical methods; from such data he can proceed to construct a complete picture of the hidden rocks below the surface, and he is then in a position to advise the engineer of the most suitable localities in which to bore for water.

FIG. 11.—Last year's drought brought home the need to find additional water supplies. The photograph, taken in August 1949, shows the Derwent Reservoir, which supplies Sheffield, Derby, Nottingham and Leicester. Parts of the valley that had been submerged since 1912 stood above the level of the water.

There are many rural areas where underground resources of water could be more vigorously exploited for the benefit of their inhabitants. A case in point was a small farm situated on the banks of the New Ancholme river in North Lincolnshire. Up to 1943 the occupants raised water by buckets direct from the river, and they had to boil it before use. Yet at not more than 100 feet below the ground abundant water was available, locked in the Lincolnshire limestone under artesian pressure. After a geological survey of the area, a borehole was sunk into the underlying limestone with the result that today pure fresh water rises without the aid of pumps to well above the land surface. This was no isolated case, and it illustrates how money and materials can be saved when geologists are put on the job of finding domestic supplies in remote rural areas. Water-survey work of this type has long been an important part of the Geological Survey's activities.

In conclusion, it must be stated that owing to the great variation in the geological character of the rocks of Britain, the concentrated centres of industrialisation and the likelihood of pollution, the problems of water supplies are of national importance. Fortunately our schools of research which investigate hydro-geology, soil mechanics and dam-site construction are vigorous and advanced, and the public will soon be brought to realise the value which their fundamental researches have for the welfare and continued well-being of these islands.

FIG. 1 (*above*).—The Cuscus (*Phalanger maculatus*); the fur is yellowy white with dark brown spots.

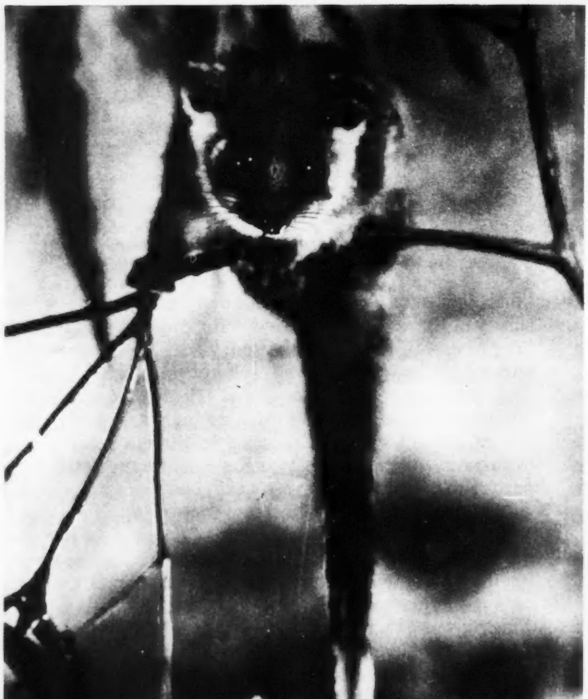
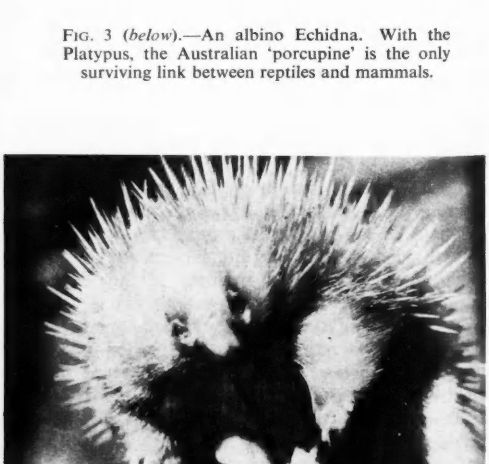


FIG. 2 (*left*).—Baby Ringtail Opossum.

FIG. 3 (*below*).—An albino Echidna. With the Platypus, the Australian 'porcupine' is the only surviving link between reptiles and mammals.



Unique Australian Mammals

ELLIS TROUGHTON, C.M.Z.S., F.R.Z.S.
Curator of Mammals, Australian Museum, Sydney

FROM the beginning the discovery and exploration of Australia was associated with the discovery of unique kinds of mammals which became the subject of animated controversy among scientists. The reason for this absorbing interest was that ancient geological isolation had made the island-continent both a cradle and vast sanctuary for the evolution of marsupial life. Although the original opossums, and several other ancestral types of marsupials, inhabit the American continent, pouched animals have attained their utmost variety within the prehistoric isolation of Australia and New Guinea.

From the war-time descriptions of its dense jungles, one might suppose that New Guinea would be inhabited by mammals typical of Malaysia, such as small deer, or large cats like the peninsular tiger, and groups of chattering monkeys. On the contrary, the furred animals of New Guinea actually parallel those of Australia in the predominance of a remarkable variety of marsupials or pouched mammals. On the mainland, as in New Guinea, only four out of the fourteen odd orders of the mammalian class became established during prehistoric times; namely, the egg-laying mammals represented by the platypus and its spiny ant-eater relatives, the marsupials, numerous native mice and rats, and the flying mammals known as bats.

Whence came those prehistoric progenitors of the grand marsupial assembly; by what means did they reach Australasia, what of their destiny? The existence of some primitive mouse-like marsupials in South America has been regarded as evidence of an ancient land connexion between Australia and Antarctica. But the southern distances and ocean depths are so insuperably greater than are those separating Australia from northern lands. The prevailing scientific view, therefore, suggests that there was a prehistoric deployment of the ancestral marsupials along two divergent routes: the one leading to the 'dead-end' of tropical America, where a few remnants survive, and the other along intermittent land-bridges by way of the Malayan Archipelago or the Philippines, eventually to reach the sub-terminal sanctuary of New Guinea, and the final refuge of Australia.

This ancient infiltration of migrant mammals, it is supposed, took place some 125 million years ago, towards the end of the Late Cretaceous geological age, when the primitive marsupials were the dominant forms of mammalian life. The tiny creatures must have travelled by means of rafts of debris over narrow waterways, and by prehistoric land-bridges which vanished before any large carnivores had evolved to follow in their tracks and prey upon them. Certain it is that, subsequent to this ancient marsupial invasion of Australia and New Guinea, relatively impassable zoological barriers were established by natural phenomena which created a neutral or buffer zone in the region of Celebes. And so, in the relatively peaceful isolation of their strange new world, the primitive pouched migrants evolved an irregular army of marsupial types which occupied the place of several foreign orders of mammals in the course of their adaptation to every available haunt of forest and plain.

The Australian continent has been described as a colossal natural-history museum of living fossils, a definition which applies most aptly to the egg-laying platypus and the spiny ant-eater. These most primitive of living mammals, termed 'monotremes' in reference to the single aperture common to the reproductive and excretory functions, actually show traces of reptilian ancestry in the shoulder-parts of the skeleton. Prolonged isolation of Australia, probably for more than 100 million years during Tertiary times, is thus demonstrated by gradual evolution of the platypus from the age of reptiles.

Although the platypus is now generally known to be a true mammal, it is not difficult to imagine the scientific excitement aroused by the arrival of the first badly preserved specimen in England. So strange was the creature that it appeared to be an imposture, and one scientist gave it the Latin name *paradoxus*, because of the contradictions of its mammalian coat of fur, duck-like bill, and webbed feet. After discovery by colonists near Sydney in 1797, the platypus was variously called the watermole, duckbill, and even duckmole.

There followed almost a century of scientific argument which imposed considerable strain upon the *entente zoologicale*, before the mammalian status of the platypus was finally decided on the following evidence. The warm-blooded platypus is not truly amphibious, since it breathes ordinary air and will drown if held under water for more than three minutes. The so-called 'duckbill' is really a combination of the nose and mouth parts of the higher mammals, specially adapted for the gathering of aquatic life, such as worms, prawns, molluscs, insects and their larvae. The webbing of the hand is not at all like that of a duck's foot, but can be expanded beyond the digits to form a swimming paddle or folded back under the palm when walking and to free the broad nails while digging.

The burrows are of two kinds. General living quarters are usually provided for both sexes by semicircular excavations in banks beneath the roots of trees, which function as bachelor barracks during the breeding season. But the breeding burrows, extending from 10 to 60 ft. and arched to the shape of the body, are excavated by the female alone. The nesting-chamber may be lined with grasses, leaves, willow-switches, or reeds crushed by the toothless but bony jaws of the platypus. The submerged entrances shown in some pictures of the burrow are due to flooding, and are never used because the animal enters the tunnel as dry as possible and spends some time on the bank making an elaborate toilette of its fur, squeezing out water with the rubber-like hand-webs.

When retiring to lay her eggs, the platypus plugs the burrow at intervals behind her with cunning earth-barriers which baffled the early investigators, as well as natural enemies such as large pythons. The small eggs, barely half an inch in diameter, do not have a brittle shell like birds' eggs, but a covering that is leathery and compressible, as in reptiles' eggs. During the incubation period of about fourteen days, the eggs are embraced by the curled-up body of the mother so that the milk-flow is stimulated by the

spasmodic movements of the newly hatched young. The milk is exuded from enlarged breast-pores instead of from definite teats, as in marsupials and all the higher mammals —a fact which caused much of the early doubt about the platypus being a true mammal.

Following its discovery, the platypus was killed in ever-increasing numbers for its exquisite seal-like fur which was highly valued for the making of coats and rugs, each of which required from about fifty to ninety trimmed skins! Who can doubt that the unique platypus was saved from extermination within two centuries of civilised occupation of the country by the total protection rigorously applied for the past fifty years throughout its entire range in the several states?

The remarkable spiny egg-laying relatives of the platypus are often incorrectly described as native porcupines or hedgehogs because nature, quite independently, has covered them with a somewhat similar protective armour of sharp spines or quills. But the foreign porcupines are really unrelated rodents; 'spiny ant-eater' supplies the most appropriate name for the quaint monotreme, with reference to its protective quills and its natural ant-food which is gathered through the beak-like snout by the long sticky tongue. Unlike the platypus, the spiny ant-eater does not make tunnels, but relies for protection on the unique ability for gouging itself downwards under the earth, with the quills repelling attack from above. In the primitive ant-eater, nature seems to have anticipated the marsupial by providing the female with a temporary abdominal sac or brood-pouch, into which she is believed to lay her egg by some remarkable contortion of the soft underparts. The infant travels in this improvised perambulator, suckling milk that oozes from the enlarged pores, pending the stronger development of its quills, when it is safely 'parked' in the maternal nest in a hollow log or hole dug under a stump or rock.

Because of their secretive habits, and absence of teats in the platypus and spiny ant-eaters, many years had to pass before scientists agreed that the monotremes were true mammals, because of the suckling of their young. Yet more prolonged was the controversy as to the laying of eggs. Even the aboriginals had confused the eggs of reptiles and birds with those of the platypus. And so, despite a published report that two small compressible eggs were found in a box confining a platypus overnight, the egg-laying question was debated for more than eighty years. The great Professor Richard Owen believed the young to be hatched within the parent, but the famous French naturalist Geoffrey rightly contended that eggs were laid. Finally, the matter was settled in 1884 when Caldwell, a zoologist sent out specially by the University of Cambridge, announced dramatically by cable to the Montreal meeting of the British Association for the Advancement of Science that eggs of both the platypus and spiny ant-eater had been obtained in Queensland.

Because of their conspicuous hopping movements it is not surprising that the members of the kangaroo family, classified as the Macropodidae or great-footed marsupials, were the first pouched animals described from the Australian continent. As with foreign rodents such as the jerboas, the hopping physique of kangaroos has been explained as having evolved because of the efforts of miniature ancestral creatures to catch insect prey, while dodging the attacks of reptiles, birds, and a few of their flesh-eating fellows. Gradually, it is supposed, the kangaroo family developed a semi-erect posture, with slight fore-limbs and grasping hands, and hind-limbs greatly enlarged as powerful springs. Leaping speedily over the countryside, the stout yet pliable tail functions as a counter-balance and rudder, and as the third leg of a tripod when a kangaroo stops to survey the scene on tiptoe.

Unfortunately, many of the smaller kinds of kangaroos have either been exterminated or drastically reduced in distribution by the effects of settlement and ravages of the introduced wild dog and fox. Therefore, it is not generally realised that more than fifty species were evolved within the age-old isolation of Australia and New Guinea. The smallest kinds, known as 'rat-kangaroos', retain the ancestral partly insectivorous diet, while the acrobatic rock-haunting wallabies feed upon plant-roots as well as leaves and grasses. The quaint tree-kangaroos of Cape York Peninsula and New Guinea, since reverting finally to the arboreal haunts and leafy diet of their primitive ancestors, have reshortened hind-limbs, while the slender tail forms a rudder for leaping amongst the branches, and for jumping as much as 60 ft. to the ground. More typical of the family are the small pademelon or scrub-wallabies, the medium-sized brush-wallabies, and the great 7–9-ft. Great-grey Forest Kangaroo, and the Red 'Roo' of the vast inland plains, which evolved to fill the place of foreign herbivores such as deer and cattle.

A popular misconception which limits the term 'kangaroo' to the giants of the family was based on the mistaken idea that Captain Cook's party had seen the great-grey kangaroo about Botany Bay in 1770. Actually, it was at Cooktown, in Queensland, some 1500 miles northward, that Cook's party first saw a medium-sized wallaby, and a larger species, which the aboriginals called 'kanguru'. But it was 150 years earlier, in 1629 to be exact, that the Dutch navigator Pelsart provided the first known account of a wallaby or small kangaroo, when he was shipwrecked on Houtman's Abrolhos near Geraldton in western Australia. Misled by the relatively minute size of the pouched young, Pelsart wrote that "it seems certain that they grow there out of the nipples of the mammae, from which they draw their food". By notable coincidence, the first account of a newly born kangaroo making its unaided journey into the pouch (this was sent to the Zoological Society of London in 1830 by Naval Surgeon Alexander Collie) referred to the same species of wallaby.

In Australia, unending arguments about the 'mystery' of marsupial birth relate generally to kangaroos, because of the amazing disparity in size between the newly born and its parent. (The average size of the newly born kangaroo is one inch.) But the remarkably premature though definitely mammalian method of birth, due to the lack of the higher mammals' complete embryonic connexion with the parental bloodstream, is a fundamental characteristic of the entire marsupial order. Naturally, years before the discovery of kangaroos, there had been similar controversy about the birth of American opossums, with Red Indian legends about their procreation adding to the confusion. Even when the zoological fact of active birth was scientifically proven against any pouch-birth theory, controversy persisted about the method of transference of the newly born to the pouch.

ew of their
l, the kan-
with slight
bs greatly
y over the
s a counter-
ripod when
.

kangaroos
reduced in
ages of the
ot generally
ved within
uinea. The
the ances-
patic rock-
ll as leaves
Cape York
ally to the
ancestors,
tail forms
or jumping
the family
e medium-
Great-grey
vast inland
herbivores

term 'kan-
e mistaken
great-grey
, it was at
northward,
llaby, and
'kanguru'.
t, that the
wn account
ipwrecked
n western
ize of the
ertain that
mae, from
dence, the
ts unaided
Zoological
Alexander

'mystery'
s, because
newly born
born kan-
ure though
he lack of
exion with
racteristic
before the
ontroversy
ed Indian
confusion.
s scientifi-
ontroversy
the newly

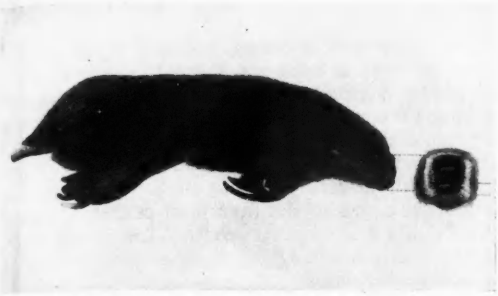


FIG. 4 (*above*).—A drawing (side view) of the Australian Marsupial Mole (*Notoryctes*). Its burrowing habits have developed such characteristics as a hard snout protected by a horny shield and powerful claws on the third and fourth fingers. The eyes have degenerated.

FIG. 5 (*right*).—The lesser Flying Opossum.

FIG. 6.—Rat-kangaroos (*Potorous tridactylus*). They are mainly nocturnal, feeding on grasses, roots and insects. One species has a prehensile tail with which it carries materials for nest building.

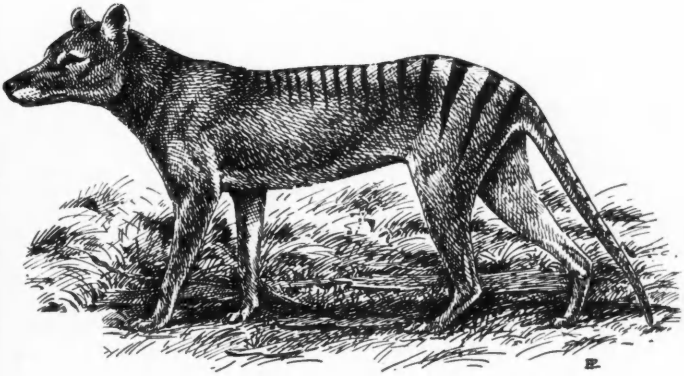


FIG. 7.—The Tasmanian Wolf or Thylacine (*Thylacinus cynocephalus*).

FIG. 8.—The first Platypus bred in captivity, in the Healesville Wild-life sanctuary in Victoria.

FIG. 9.—The Australian Spotted Native Cat (*Dasyurus*).

In 1806 Professor Barton of Philadelphia published the first observation of the unaided journey of marsupial young. The sightless young opossums, he wrote, find their way to the teats by an invariable and determinate instinct, and it is not true, as often asserted, that the mother places the young in the pouch with either her lips or paws. That the young are not born on the nipples is most simply indicated by the fact that in the American opossum, as with the Australian phalanger-possums and marsupial 'cats', the young at birth frequently exceed the number of teats. Thus the losers in this instinctive marathon are doomed to starvation and, after clinging hopefully to the tails of more fortunate fellows, their remains may often be seen in the mother's pouch.

The somewhat monkey-like Australian possums, mostly with prehensile tails, derive their family name Phalangeridae from the specialised climbing structure of the phalanges of the hands and feet. The naturalists of Captain Cook's party gave the Red Indian name 'opossum' to the leaf-eating Australian ring-tail, but the American marsupial is a flesh-eater and more akin in habits to the Australian pouched 'cats'. Smallest of the phalangers are the pigmy-possums, known as 'dormice' to the early colonists, and the little honey-possum of south-western Australia, which thrusts its tapered snout and brush-like tongue into blossoms after insects, pollen and nectar, like the honey-eating birds.

Several phalangers have evolved a gliding kind of flight with side-flaps stretched between the limbs. The smallest is the insectivorous feather-tail glider, with the hairs of the tail arranged to form a feather-like rudder. The largest is the possum-glider, which is a leaf-eater capable of making downward glides of about 120 yards. Best known of typical phalangers are the grey or brush-tail possums, the rich fur of which once caused excessive exploitation for the fur trade; this animal is now protected by law. Largest of the phalangers is the cuscus, occurring also in Celebes, Timor and New Guinea. Its diet is of small lizards, birds and mammals, as well as foliage, and its rounded face, short ears and partly naked prehensile tail have inspired false reports of monkeys being seen on Cape York Peninsula.

That unique marsupial, the koala, originally likened to a foreign sloth, and most inappropriately called 'native bear', is usually regarded as a tailless member of the phalanger family. But besides the complete degeneration of the tail, there are distinctive anatomical features which justify placing the koala in a separate family. Eventually, it may prove to be more closely related to the tailless and burrowing wombat than to the tree-haunting phalangers. The most desirable popular name 'koala' is based upon an aboriginal word implying that it seldom drinks in the wild state, apparently deriving sufficient moisture from dew and its diet of eucalyptus leaves. Enslaved to its ever-shrinking environment, the slow-breeding koala has proved no match for the hazards of settlement, coupled with epidemic diseases and past slaughter on an unconscionable scale for its rich fur. The fascinating koala is utterly harmless anywhere and, in addition to the total protection now afforded, it is desperately in need of adequate forest sanctuaries where it may browse in the perpetual peace that is its natural heritage.

The marsupial wombat, known as a 'badger' to the early colonists, somewhat resembles a beaver minus its tail. Because of its stout build and shovel-like nails it is well equipped for digging large burrows which may eventually link up to form tunnels about 100 ft. long. A single young one occupies the female's pouch, while comfortable tunnel nests are made of bark and the grasses which form its diet, together with tender roots and fungi. Unfortunately, wombats have been driven from most of their mainland haunts because of damage they cause to fencing and crops, and the deep tunnelling which endangers stock and obstructs rabbit control.

The bandicoots, ranging in size from a large rat to a hare, are easily mistaken for small kangaroos because of their elongated hopping feet. But they are a separate family of marsupials which have retained the ancestral insectivorous dentition during gradual adaptation for a mixed diet, including vegetable matter and small reptiles and mammals. The popular name bandicoot, meaning 'pig-rat', actually applies to a large rodent common to southern India and Ceylon. Because of outward similarity, it was apparently first applied to the Australian marsupial by the explorer Bass in 1799. The family is represented by a variety of quaint species in Tasmania and New Guinea, as well as on the mainland.

A remarkable example of parallel evolution, in remote isolation, is represented by the marsupial mole of the sandy regions of central and western Australia. Like the true moles of Europe and South Africa, it is sightless, but perfectly adapted for living and feeding underground. It is a true marsupial, and carries its young in a pouch opening to the rearward. Another extremely specialised marsupial is the banded termite-eater, which has its tongue and teeth remarkably modified for the gathering and mastication of 'white-ants'. Literally a living fossil, this strikingly coloured and useful little marsupial was once quite plentiful on the inland plains of New South Wales, but settlement has banished it to the more remote central regions.

The smallest of the predatory marsupials are the so-called pouched mice and rats, which not only consume quantities of insects, but also kill lizards and small birds, and are special enemies of the common mouse. There are about thirty species, including the hopping kind of pouched jerboa, all of which are recognisable by their finely tapered snouts with several small upper and lower front teeth, instead of the paired chisel-incisors of the true rodents. The larger spotted marsupials, known as native and tiger 'cats', are more like foreign weasels in their predatory attacks on poultry, but otherwise are useful feeders on insects, rats and young rabbits. The Tasmanian wolf or thylacine, which is probably the largest marsupial of all time, provided a remarkable parallel with the canine family in its external appearance. It is also known as the pouched 'tiger', in reference to the camouflage stripes across its back. Preying originally upon native birds and mammals, the 'wolf' naturally became a destroyer of sheep and poultry, so that it was hunted to the verge of extinction. Though greatly feared by the early colonists, it will not attack man unless hopelessly cornered, but will fight a dog to the death. Despite the fact that this powerful marsupial predator was banished from the mainland in prehistoric times, going down before the dingo, it seems likely that the secretive creature will survive amongst the dense uninhabited forests of southern Tasmania.

FIG. 1.—The University of Cape Town, successor to the first South African College, lies on the slopes of Table Mountain and looks down upon the suburbs of the city.

Science in South Africa*

H. B. S. COOKE, F.R.S.S.Af.

APART from the early expedition of Simon van der Stel in 1685 to look for copper in Namaqualand and occasional later searches for workable coal deposits, interest in the geology of South Africa seems to have been very slight until the middle of the nineteenth century. The father of South African geology was Andrew Geddes Bain, whose career bore many resemblances to that of William Smith in England. Bain, like Smith, was a road engineer, but it was not until he was forty years of age that his scientific interest in rocks from a scientific viewpoint was aroused by his chance discovery, in 1837, of Lyell's *Principles of Geology*. He then began a diligent search for fossils and soon despatched a large collection of fossil reptiles from the Karroo to the Geological Society of London, where the importance of the fauna was recognised by the great palaeontologist, Sir Richard Owen. By 1851, Bain had completed a remarkable geological map of the southern Cape.

Largely because of Bain's pioneering efforts, the Government began to take an interest in geology. It was not until 1896, however, that a systematic survey was begun under the Cape Geological Commission. In the following year, the South African Republic appointed a State Geologist in the Transvaal but the outbreak of the Anglo-Boer War curtailed his activities. The various scattered efforts were consolidated in the single Union Geological Survey which came into being after the union of the four territories in 1910. Most of the country has now been geologically mapped on a small scale and it is probable that more is known today about the geology of South Africa than is known about any other territory of the continent of Africa. Nevertheless, a great deal remains to be done and research is proceeding actively, not only in the Geological Survey, but also in the universities and under the many mining companies interested in mineral development.

Possibly the most outstanding figure in South African geology was Dr. A. L. du Toit, whose death in 1948 was a loss, not only to his own country, but to international geology. Du Toit was truly a South African, for his forebears came to the Cape in 1687. His mapping ability was exceptional. Apart from his admirable work in South Africa, he made a prolonged tour of South America and was so impressed with the geological similarities between that country and his own that he became a strong supporter of the Wegener hypothesis of drifting continents; but whatever the final decision may be about continental drift, du Toit's data on the subject will always be of outstanding value.

The first reptile fossil from the Permo-Triassic Karroo Beds was collected by Bain in 1838, but until 1897 all such

* In the first part of this article which appeared in the April number, Dr. Cooke described pioneer scientific work in South Africa and later developments in astronomy, geodesy, physics and geophysics.

specimens were studied in Europe or in America by overseas experts. In 1897 Doctor Robert Broom arrived at the Cape. He was born in 1866 at Paisley, Scotland, and studied science and medicine and spent some years in medical practice in Australia before coming to South Africa. His medical practice was but a background for an enthusiastic pursuit of research upon the abundant reptile fossils of the Karroo to which he devoted his life. These fossils exhibit a wide variety of forms which, in their fifty or sixty million years of evolution, covered almost the entire structural gap between the primitive ancestral reptiles and the earliest mammals. These animals ranged in size from that of a rat to monsters more than twelve feet in length and in habit from sluggish, herbivorous swamp-dwellers to active carnivorous creatures. Many expeditions from Europe and America have visited the Union of South Africa to collect and study the mammal-like reptiles (Therapsida) but South Africa is no longer backward in this field and several of the museums have palaeontologists at work. An Institute for Palaeontological Research was founded recently at the University of the Witwatersrand in Johannesburg.

The mammal-like reptiles are by no means the only fossil groups from South Africa which have proved to be of exceptional interest, for its limestone caves have yielded remains of man-like creatures which lived in southern Africa about a million years ago. The first of these South African fossil ape-men was found at Taungs and was described by Professor R. A. Dart of the Medical School in Johannesburg as *Australopithicus africanus*. The skull was that of a child, and many eminent authorities rejected its man-like characters which they thought might not be present in the adult form. In 1936, however, Dr. Robert Broom discovered remains of an adult at Sterkfontein, and quite a number of specimens have since been found at several localities, and today experts feel there is little doubt that these fossils lie very close to the ancestral stock from which man arose. The modern view is that it is very likely that Africa, and not Asia, was the cradle of the human race.

Tools of the Stone Age are very abundant in this part of Africa, as they are also in the rest of the continent, and they range from the most primitive chipped pebbles to beautifully fashioned arrow-heads, spear points and other articles. Few parts of the world can show a more complete series of examples of every stage of human development as reflected in the tools which man has used. The doyen of prehistorians, the Abbé Breuil, has spent many years in South Africa studying the tools and the rock paintings in company with such local experts as A. J. H. Goodwin of Cape Town and Professor C. van Riet Lowe, Director of the Government Archaeological Survey. (South Africa, incidentally, is one of the few countries in the world to possess such a government centre for archaeological research.)

FIG. 2.—An exhibit in the Transvaal Museum, Pretoria, showing the family tree of man and his relatives. The South African fossil ape-men are on the lower left branch of the tree.

Biological Research

In South Africa, the biological sciences have progressed in a steady but unspectacular manner. In the early days of settlement, studies in natural history were undertaken by visitors to the Cape, who took collections of material away to Europe for study and description. In consequence the type specimens of most of the typical South African plants, birds and animals are stored in museums or other institutions in Europe and are not readily accessible for examination and comparative work undertaken in the country of their origin. This has been, and will probably continue to be, a severe handicap to systematists working in South Africa, but today systematic botany and zoology are receiving increasing attention in local institutions.

The Swede, Karl Thunberg, who arrived at the Cape in 1772, gave the first good account of the unusual Cape flora, and he has been justly termed the father of South African botany. Many other visiting collectors made important contributions, but it was not until 1863 that a Cape Government Herbarium was established at Cape Town. A full account of the Cape flora was begun by Dr. William Harvey at the Cape in collaboration with O. W. Sonder of Hamburg, and the first three volumes of their *Flora Capensis* were published between 1859 and 1865. The work was ultimately completed at Kew and the final volume appeared in 1933.

Applied botany is, of course, regarded as a

FIG. 3.—The South African Institute for Medical Research in Johannesburg.

most important subject in a developing agricultural country and the semi-arid climate of much of the interior of South Africa creates many peculiar problems which require local research for their solution. Plant breeding is energetically undertaken by many institutions with excellent results. The soft fruit industry of the Cape has developed to such an extent that it now has a very large exportable surplus. The Cape wine industry, which has grown out of the small vineyards established in the seventeenth century, is also a major exporter, and constant research underlies the improvement of the vines and of the wines and brandies which are produced. Quite recently, South Africa has discovered the technique for producing the surface yeast mass known as 'flor' on sherries, hitherto regarded as being confined to Spain.

Agricultural development and the general expansion of permanent settlement, has seriously disturbed most of the wild animal life of the country and the big herds of antelopes, which once roamed the entire area, have vanished or been confined to strictly protected parks. In 1799, the German traveller Lichtenstein, for example, had to go five hundred miles from Cape Town before he could find a rhinoceros, whereas old records show that these animals had been an active menace to the first settlers. Now they live only in reserves.

Perhaps the foremost of the great naturalists who studied the wild life of South Africa was the Englishman, William Burchell. He travelled extensively in the early nineteenth century and journeyed north as far as the Molopo River. His meticulous observations of the habits of the animals encountered are invaluable today in reconstructing former conditions and his accurate—and often lively—drawings are of artistic as well as of scientific merit. The four large volumes produced by Dr. Andrew Smith also represent an outstanding contribution and the loss of the important collections from his first South African Museum is a serious one.

The museums very naturally play a leading role in taxonomic and descriptive zoology. Two general works of particular importance were produced by W. L. Sclater and by F. W. FitzSimons. In 1900 Sclater published two volumes on the mammals of South Africa and he collaborated with A. C. Starke in producing four volumes on the native birds. With Dr. Oldfield Thomas, Sclater also wrote a magnificent treatise on antelopes. FitzSimons, in 1919, produced the first instalment of his six-volume work, *The Natural History of South Africa*; there are four books dealing with mammals and two with birds. He established a snake park at the museum in Port Elizabeth and was one of the pioneers in producing an effective antidote for snake-bite. His son, V. FitzSimons, has also achieved prominence as an expert on reptiles.

Fishing is a major industry and consequently marine biology has been encouraged. A Government Marine Biologist was appointed in 1895. Apart from research with a practical bias, much descriptive work was done by the South African Museum and, in recent years, by Dr. J. L. B. Smith of Rhodes University College, Grahamstown. This

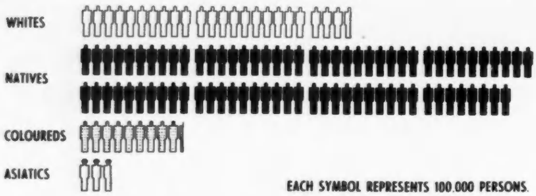


FIG. 4.—The composition of the population of the Union of South Africa, 1948.

has culminated in his production, in 1949, of an impressive volume on *The Sea Fishes of South Africa*. Amongst the many fish which Smith has described is one of unique interest caught by a trawler near East London, Cape, in 1938. This was a living example of the Coelacanth group, which had hitherto been believed to have died out in the Cretaceous period, sixty million years ago. No further specimen has come to light, but an extensive search for this fish is under way.

All the domestic animals of South Africa are imported, even the native African cattle having come from the north, and most are not well adapted to the climatic conditions. Research is required before the production of improved breeds is possible although the poor native African cattle have already been greatly improved through breeding experiments and there is a prospect that these types will ultimately prove to be of great economic value.

Introduced animals, as well as those native to the country, are subject to infection by a wide variety of diseases, both local and introduced. Breeding and selection can bring about a certain degree of improvement in some cases, but in general, specific measures are necessary to safeguard animal health. Stock farming had scarcely begun to find its feet in the interior when, in the 1890s, diseases wrought terrible havoc and threatened to wipe out the whole cattle population. A young Swiss veterinarian, Arnold Theiler, was called upon to develop protective measures and from his small laboratory grew the large Onderstepoort Veterinary Research Institute, known all over the world for its researches. The Institute has developed many vaccines and sera which it distributes to farmers.

Great public interest has recently been aroused by measures taken against the tsetse fly in Zululand. This fly carries the trypanosome parasite of nagana but not, in South Africa, of human sleeping sickness. Spraying from the air with DDT has virtually eliminated the fly from the infected region, but this area is small compared with the vast expanses of Central Africa which are infected and it cannot be assumed that such measures would be effective there.

The problem facing the human inhabitants of South Africa are rendered unusually complex by the varied nature of the population. The original inhabitants were small, brown-skinned people known as Bushmen, Hottentots and Korannas. When the first Europeans visited the Cape, they found in these peoples a living remnant of the Stone Age. The land of the brown folk was invaded from the north by tall black Bantu-speaking peoples, who had reached the Zambezi by the tenth century A.D. These black people consist of a number of distinct groups with differences of culture and language as great as those which separate most European nations. The European invasion from the south then squeezed the brown men into the arid Kalahari region, where a few hundred still survive, or absorbed them into the group of mixed races, known as the 'Cape Coloured' (which includes a goodly proportion derived from Malay slaves). From 1860 onwards Indian labourers were introduced into Natal for work on the sugar estates and many remained to form the nucleus of a permanent Asiatic community.

This multi-racial and multi-lingual assemblage of peoples, each with their own cultural, religious and dietetic customs, creates many problems which require sociological studies.

The health of the varied indigenous population is adversely affected by the disturbing effect of white civilisation upon the native way of life. Malnutrition amongst the natives is widespread, though actual deficiency diseases are seldom apparent. Vital statistics for large sections of the population are virtually lacking and are difficult to obtain amongst illiterate peoples. Data are slowly being accumulated but the task is a vast one.

General health matters are supervised by a Government Department of Public Health and research on widespread diseases is one of its functions. Some of this work has been done in collaboration with the independent South African Institute for Medical Research, which was created in 1911 through the efforts of the gold-mining industry of the Witwatersrand. Although some medical laboratories are run by the Department of Public Health, the South African Institute for Medical Research provides the main medical laboratory service for the Union. It manufactures most of the vaccines and sera required for the country, but basic research work is still one of the principal functions of the Institute.

In its early days, the Institute paid particular attention to medical problems connected with the mining industry and its researches were largely responsible for the reduction of the pneumonia death rate there from 40 per 1000 in 1911 to around 1·5 per 1000 since 1930. This figure has been reduced to 0·6 per 1000 since the introduction of the sulpha drugs. The Institute has also done a great deal of research into silicosis and, as a result of measures now applied, this disease is no longer a scourge of the mining industry. South African experts have advised and assisted other countries on silicosis problems.

Quite recently the Council for Scientific and Industrial Research (which was established in 1945) has been responsible for bringing about a substantial increase in medical

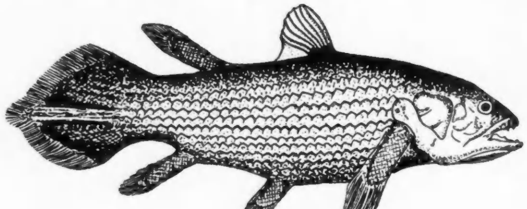


FIG. 5.—*Latimeria chalumnae*, a living example of a group of fishes thought, until its discovery in 1938, to have been extinct for sixty million years. (From *Evolution* by Chapman Pincher; Herbert Jenkins, 1950.)

Dr. A. L. Du Toit

F. W. Fitzsimons

Sir Arnold Theiler

Sir Spencer Lister

Dr. B. F. J. Schonland
Director of C.S.I.R.

Sir Robert Broom, F.R.S.

research in South Africa. In addition to its financial support of individual research workers, it has been instrumental in establishing in the medical faculties of the universities, or at other institutions, about a dozen research units each of which deals with an outstanding problem of medical research.

Until the latter part of the nineteenth century, research work in South Africa was mainly the result of the initiative of individuals backed by institutions overseas. Some research was undertaken at the university colleges and at the museums, but little was done by the Government. During the closing two or three decades of that century, systematic research began to become a Government concern and individual research received encouragement and stimulation through the foundation and growth of scientific societies. It was not until the Union of South Africa came into being in 1910, however, that scientific research really became established and received full official support. The Department of Agriculture soon developed a number of research branches and these have grown to such an extent that it is today directing a large proportion of the research which is being conducted in the whole country.

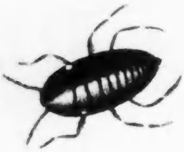
In 1918 the Government established a Research Grant Board which was to assist in stimulating and organising research outside the Government departments. From the limited funds voted to it by the Government, it made grants to help experienced research workers and, through the universities, to aid post-graduate research students.

After the recent war, the functions of previous bodies of the nature of the Research Grant Board were taken over by two new organisations, the Council for Scientific and Industrial Research (C.S.I.R.) and the National Council for Social Research. The latter was founded in order to promote, organise and assist educational, sociological and humanistic research on a national basis and, when necessary, to create bodies for the conduct of long-term researches. The C.S.I.R. performs a similar function in respect of the natural, medical and physical sciences, and corresponds to Britain's Department of Scientific and Industrial Research. Agriculture is more or less excluded from the scope of the C.S.I.R. since the Government Department of Agriculture caters adequately for that field.

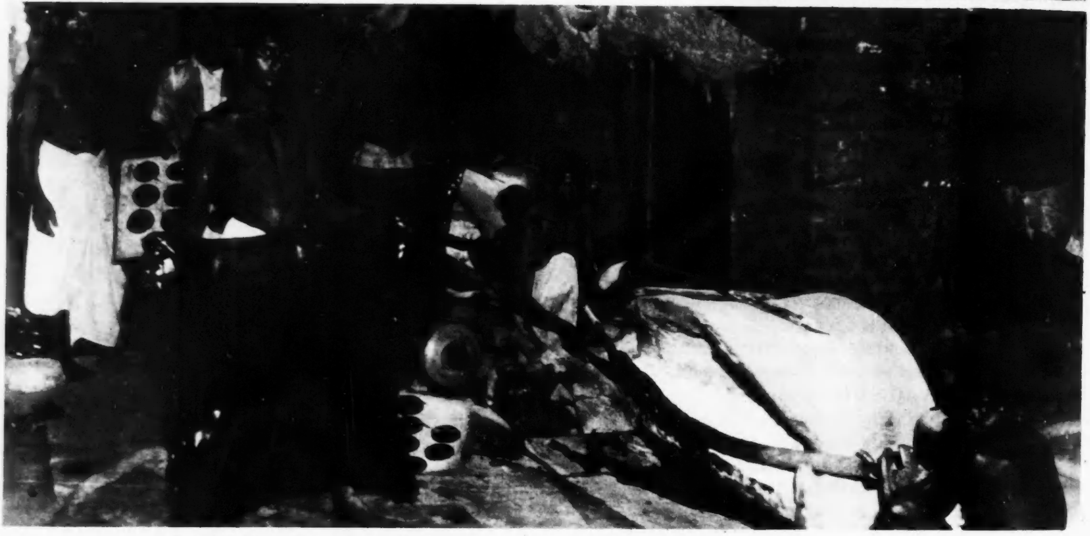
In addition to handling grants for scientific research to individuals, the C.S.I.R. is directly responsible for the establishment and maintenance of national research institutes, of which five are at present in existence: National Building Research Institute, National Physical Laboratory, National Chemical Laboratory, National Institute for Personnel Research and a Telecommunications Laboratory. It is represented on the boards of a number of other bodies, such as the South African Institute for Medical Research, and works in close association with such institutions as the South African Bureau of Standards, the Fuel Research Institute and the Government Metallurgical Laboratory. The C.S.I.R. also plays an important part in encouraging the formation of industrial research associations, which it helps to subsidise.

With the advent of the C.S.I.R. a real co-ordinating influence has become apparent in South Africa for the first time. Facilities which individual institutions could not formerly afford to provide are becoming available in C.S.I.R. laboratories and can be used by those who require them. The subsidisation of research in South Africa is being more freely encouraged than ever before and it is already obvious that a new era of progress in scientific research has begun. Furthermore, it now seems likely that, as a result of the conclusions reached at the recent African Regional Scientific Conference (convened by the C.S.I.R.), this co-ordinating influence may spread farther afield and the special facilities of individual institutions throughout Africa may become more widely available.

In concluding this account of science in South Africa, the writer would like to emphasise that it has been impossible to cover the whole field; only a few illustrative examples have been chosen and some main trends of development outlined. Finally, the writer wishes to acknowledge his indebtedness to the Council for Scientific and Industrial Research for permission to draw upon information collected by him initially on their behalf.



Valuable to man are the Cochineal Insect (*left*, seen on prickly pear) and the Lac Insect (*above*). The right-hand photo shows a basket of stick lac.



Interior of a typical shellac factory. Seed lac is placed in a long sausage-shaped cotton bag, melted before an open charcoal fire and squeezed through the bag to separate as much dirt as possible. The lac is then placed on a glazed earthenware cylindrical hot water bottle to keep it pliable. When sufficient lac has been collected, it is removed and stretched into sheets which on stretching and cooling become brittle. The lac is now in 'shellac' form and is subsequently broken up for packing.

(*Left*) Mussel Scale (*Lepidosaphes ulmi*) on trunk of apple tree. Ministry of Agriculture photo. (*Centre*) Hemisphaerical Scale (*Saissetia coffeae*) on oleander. Photo by P. C. Brown. (*Right*) An orange infested with scale insects (*Lepidosaphes*).

ANYONE
on their
brown n
costs the
thousand
prosperit
These
of all the
which m
of the ar
Scale
family C
which als
and the v
guishes t
various f
of this t
you actu
ensconce
'mussel-s
noticed i
trees. Th
is not at
coccid.
different
130 diffe
others ar
as, for
Cryptoco
It is p
of the
remark t
most anc
good rea
show the
first gen
second g
while ot
winged,
genesis,
ently sel
as *Lecan*
unknown
One o
the adul
some so
to no suc
insects;
are wing
found.
wings, t
little in
and do,
probably
female i
antennae
the cocc

Scale Insects

PETER B. COLLINS, B.Sc., A.R.C.S.

ANYONE buying oranges recently must often have noticed on their skins a number of small pear-shaped or lenticular brown marks. These are scale insects, whose presence costs the world's citrus fruit industry many hundreds of thousands of pounds annually, and on whose control the prosperity of big areas of the world now depends.

These and their relatives are among the most successful of all the insects; they owe their success to certain features which make them unusual in even that very varied class of the animal kingdom.

Scale insects belong to the sub-order *Homoptera* and family *Coccidae*, of the order *Hemiptera*—the 'bugs', which also includes such pests as the aphids, the bed-bug, and the white-fly of greenhouses. The feature which distinguishes the scale insects is a covering of wax, which takes various forms in different sub-families; it is to the presence of this that they owe most of their success. This is what you actually see on your orange; the insect itself is safely ensconced beneath it. You see it, too, as the familiar 'mussel-scale' on apple and other fruit trees; you may have noticed it in another form as the 'woolly blight' of beech trees. There is, in fact, no order of the higher plants which is not attacked by one or more species of scale insect or coccid. Some are found on a tremendous number of different hosts (*Lecanium ulmi*, for example, occurs on over 130 different species, including many different orders); others are rigidly confined to a single species of host plant, as, for example, the beech coccus referred to above, *Cryptococcus fagi*, which occurs on that tree alone.

It is partly this excessive variation in habit on the part of the coccids which caused the late A. D. Imms to remark that "this family in some respects is one of the most anomalous of all insects". There are, however, other good reasons for this remark. Some groups, for example, show the phenomenon of alternation of generations: the first generation have wings, and they may give rise to a second generation, some of which are like their parents, while others are wingless. The next generation may be winged, and start the cycle over again. Then, parthenogenesis, the production of a fresh generation from apparently self-fertilised females, occurs in some groups (such as *Lecanium ulmi*), in which the males are completely unknown

One of the few regular characteristics of coccids is that the adult females are always wingless, and always have some sort of specialised covering. The adult males adhere to no such rules: some are winged, active and quite normal insects; others have wings which are never used; others are wingless; and of some species males have never been found. Moreover, apart from the universal absence of wings, the females of the various sub-families have very little in common. Some when adult are active and can, and do, move about; others are more or less degenerate, probably reaching the lowest state in *Physokermes*, whose female is "a sac-like object devoid of any vestiges of antennae or legs". These idle habits are encouraged by the coccid's method of feeding, which is to insert a long proboscis into the tissues of its host plant and sit there, sucking the sap, for the rest of its life!

Metamorphosis, that system of growing up which is best known in the egg-caterpillar-chrysalis-imago of the butterflies and moths, is also highly anomalous in these peculiar insects. Most of the Hemiptera have a simple series of stages, hatching from the egg as young nymphs which are smaller, less developed, but none the less fairly recognisable replicas of their parents. But not so the coccids. In some species, there is only one larval stage between egg and adult; from this, every variation is found to four complete larval stages, and, in some species, an almost completely quiescent stage may occur half-way through the life-history. Normally, as one authority remarks, "the females become grub-like or bag-like, while the males become insect-like". Yet even here the rules are not adhered to; the female may, when adult, desert her static home and start wandering about, in direct contradiction to the procedure generally adopted throughout this group.

Whatever the means taken to achieve success, there is no doubt about the extent to which the coccids achieve it. They include some of the most virulent and notorious pests in the whole world. Typical of these is the Red Scale of citrus fruits, *Aonidiella aurantii*, which has the awkward habit of producing resistant strains, of which only 97% can be killed by the highest practicable dose of fumigants as ferocious as hydrocyanic acid gas, that under normal conditions is so toxic that it is capable of killing the human personnel handling it. Just how resistant these strains are may be gathered from the fact that 'normal' (that is, quite low) concentrations of the fumigant can be relied on to give 100% mortality against non-resistant scales, under field conditions. But even under laboratory conditions, using even higher concentrations of the gas in a special gas-tight metal 'fumatorium', 1% of the resistant strain were still alive after a 45-minute exposure to the gas. As a single badly infested tree may have 500,000 scales, each survivor of which may produce 50 to 150 young, even this 1% survival is a matter of concern to the growers. It seems that this resistance is a sex-linked character which has probably always been present in a minority of individuals. The fumigation, by killing off all the susceptible scales, enables a much more concentrated population of those bearing the resistance factor to be built up, so that eventually only that strain is present!

Other important scales attacking citrus fruits are *Chionaspis citri* and *Lepidosaphes beckii*, the yellow and purple scales respectively. Between them, these two species infect the orchards of every citrus-growing country in the world. The fact that both can thrive on many other sorts of tree makes them even more difficult to control, since there are always natural reservoirs from which reinfestation may take place. Just how much these and other scale insects cost annually is impossible to calculate, but it is worth noting that in 1938 an estimate of about 8,000,000 dollars per year was given as the cost of citrus pests in California alone.

In Britain, we are fortunate in having few scale insects that are pests, for the members of this group flourish chiefly in the tropics and sub-tropics. There is, however, the mussel scale referred to above, while the oyster-shell bark louse (*Aspidiotus ostraeformis*) is another species attacking fruit trees. Nor are our fruit trees the only victims; in hot-houses, the soft scale (*Lecanium hesperidum*) makes a great nuisance of itself by secreting, instead of a protective scale, vast quantities of honey-dew, which covers the leaves of its host plants with a sticky mass. In the outdoor garden, a near relative (*L. corni-crudum*) makes a similar mess of the yew hedge. Finally, even the aspidistra has its own special pest (*Pinnaspis aspidistrae*).

Apart from these innumerable and costly pests, the coccid family can still, in one or two cases, be of benefit to man, and as a matter of fact its beneficial members have probably been much longer appreciated than the harmful ones. They include the members of the genus *Tachardia*, which produce lac; the 'pseudo-gall' coccid, *Kermes*, from which comes the dye of that name; the Chinese wax insect, *Ericerus pe-la*; and, finally, the cochineal insects. The shellac of commerce is the wax secreted by the lac insect (*Tachardia lacca*), which lives in India, Burma and Assam, as well as the Far East. The insect lives chiefly on trees of the fig family, and is said to have at least sixty different host plants. No cultivation is undertaken, all the lac being collected off wild trees, in the form of 'stick lac', that is, twigs encrusted with the mass of scale insects in their waxy coverings. Ground up in water to extract the colouring matter, it becomes 'seed lac', and after this treatment yields various other products, among them shell-lac. Some idea of the wide use of this insect may be gathered from the fact that before World War II 25,000 tons were said to be collected annually from the Central Provinces of India alone, being worth about £300,000.

'Kermes' is used both as the name of the dye and that of the species from which it comes, *Kermes ilicis*, which infests a low, shrubby species of oak common in the Mediterranean region. The bodies of the female insects, which resemble small seeds or galls, are dried and crushed to form this dye, which was used from the earliest times by all the great civilisations of the Mediterranean region, and which only began to decrease in popularity with the advent of cochineal. Three sprigs of the oak tree itself still form the crest of the Dyers Company.

The Chinese wax insect (*Ericerus pe-la*) is deliberately cultivated in its native country; although it is the females which are the subject of cultivation, the wax is got from the males which they produce. The wax is clear, white, and very hard, and until the introduction of tallow was widely used in China for candle-making. The females of the group to which *Ericerus* belongs are among the more degenerate coccids, the body having lost all signs of being divided into segments as in any normal insect, only the presence of antennae and legs indicating which part is which!

Most valuable of these useful coccids, however, is still the cochineal insect, *Coccus cacti*. This was already in use as a source of dye in Mexico in the early sixteenth century, when importation into Europe began. At one time some 800,000 lb. were imported annually (comprising about 56,000,000,000 insects) and the value of those used in England alone was about £300,000 per annum. Adult, but unfertilised, female insects are said to be the best; they are brushed from the plants into containers, killed by heat, and then treated in various ways to extract the dye. The use of these dyes has, of course, decreased since the establishment of the synthetic dye industry, but there are still those who swear that no real imitation of the true cochineal dyes has been perfected.

The host plants of the cochineal insects are cacti of the 'prickly pear' genus (*Opuntia*), in connexion with which another, and very different, use is to be recorded on the credit side of the scale insects' account. The 'prickly pears', introduced originally for their fruits, have quite overrun vast areas of Australia and South Africa; to control them by encouraging vast numbers of cochineal insects seemed an obvious possibility, and in South Africa especially this has been very successful. (In Australia, better control is obtained by the *Cactoblastis* caterpillar, but should this fail for any reason, scale insects such as *Dactylopius opuntiae* are always present and ready to increase and re-establish control on their own.)

In South Africa, too, the coccids on prickly pear are valuable in an even more indirect and curious way: for they provide a convenient store of food on which to rear a species of ladybird which is itself used as a predator against another coccid, the mealy bug, *Pseudococcus*, that attacks citrus fruits! This leads us into the realms of 'biological control', which has been used successfully against a number of species of scale insect. In fact, the first classic instance of this type of control was probably the use of the ladybird *Rodolia cardinalis* against the cushiony cotton scale, *Icerya purchasi*, which in the 1880s was having a disastrous effect on the Californian citrus groves. Various methods of control had been tried with little success, yet little more than a year after its introduction (in 1888), *Rodolia* was giving almost complete control; this has been repeated on many later occasions when *Icerya* has become a pest in other parts of the world. *Icerya* belongs to a group of scale insects in which the female rests on top of the waxy secretions, instead of being covered by the scale, as in most groups. The wax forms an 'ovisac', which may take as long as 90 days to secrete and may contain up to 1000 eggs.

In another of the primitive coccid sub-families are found the 'ground-pearls', *Margarodes*. These objects are cysts secreted underground by the females . . . for they live beneath the surface of the soil, often in ants nests; in the West Indies and elsewhere they are made into necklaces and similar ornaments.

Despite its infinite variety, the family of coccids is one about which entomologists have still a great deal to learn. We must be continually on the watch for the spread of these insects as pests, for, as has been shown, they are extremely difficult to control and, once established, virtually impossible to exterminate. It is therefore with the more interest that those of us who grow apples may learn, for example, that the San José scale, *Aspidiotus perniciosus*, a world-wide species known as a virulent pest of apples and pears, has since the war become a major pest in certain parts of Germany. There, it is already considered sufficiently serious to be made the subject of posters and public warnings of a nature more usually associated, in Western Europe at least, with such pests as the Colorado Beetle.

(*The shellac photographs are reproduced by permission of Col. W. F. Rhodes.*)

To meet the world demand for petrol, twice as much crude oil would have to be brought out of the earth were it not for the processes of cracking, among the most important of which is catalytic cracking.

Catalytic Cracking

DENIS SEGALLER, B.Sc.

THE term 'cracking' as used in industrial chemistry means just what the word suggests: the breaking-up of something —of a molecule, in fact. The older, more academic word 'pyrolysis' means literally 'breaking by fire', and this is what the cracking process is—the breaking down, by intense heat, of large molecules into smaller ones. We can picture the process if we remember that heat is the outward manifestation of random molecular motion, and temperature, the manifestation of the average speed of that motion. In cracking, the temperature is high and the molecular speed is so great that the molecules are shattered into smaller ones.

Cracking was known as a laboratory phenomenon over one hundred years ago, but its adoption as a large-scale industrial process by the oil industry was a direct consequence of the rapid development of the internal combustion engine during the first decade of this century.

The crude petroleum which comes from the oil wells is a brownish viscous liquid; this is a mixture of a great many different hydrocarbons, i.e. substances whose molecules are composed of atoms of the two elements carbon and hydrogen. The hydrocarbons present in crude oil range from solids or semi-solids (such as bitumen or wax) that are composed of very large molecules containing five hundred or more carbon atoms, to light, volatile liquids composed of very small molecules with as few as five carbon atoms. The crude oil is separated by distillation into useful components or 'fractions'; each fraction is a small group of hydrocarbons whose boiling-points all lie fairly close together, and whose molecules are all very approximately the same size. The main fractions from a marketing point of view are gasoline (petrol) which is the lightest, kerosene (paraffin oil), diesel oil, lubricating oil, and at the heavy end bitumen, wax or heavy fuel oil, depending on the geographical location of the oilfield from which the crude oil came.

At the beginning of the century kerosene for oil lamps, heating and cooking was the chief marketable fraction. Most of the lighter fraction, gasoline, obtained as a by-product in the distillation of kerosene, was burnt as waste—a procedure which would horrify the coupon-bound motorist of today! But the arrival of the motor-car soon changed the picture, for with its ever-increasing popularity, the demand for gasoline before very long far outstripped that for kerosene. And as more and more cars appeared on the roads the demand for gasoline grew so fast that many new oil wells had to be drilled to produce the crude oil from which the gasoline could be distilled. But immediately there came another problem, this time in the form of a glut: a glut of the heavier fractions left over after the gasoline had been removed. There was no ready market for the huge volume of heavier oil products so produced. And still the demand for gasoline rose.

Thus the oil industry was faced with a dual economic problem: and a possible answer was to try to convert the excess heavy components into the much-sought gasoline. To this end the known laboratory process of 'cracking' seemed a likely step. Petroleum chemists turned their attention to this process and in 1912 William M. Burton in Indiana, U.S.A., successfully applied heat under pressure to a heavy oil fraction in the laboratory, and produced the first 'cracked' gasoline. By means of the heat he had cracked or broken the large hydrocarbon molecules of the heavy oil into smaller molecules of gasoline.

Full-scale industrial cracking plants were soon developed from Burton's laboratory technique, and within three or four years these were supplying enough extra gasoline to keep up with the demand. Individual plants varied in design, but the principle in all was that of the original laboratory experiment—the heavy fractions were heated under pressure (so as to keep them liquid at the high temperatures needed to bring about cracking—the so-called 'liquid-phase' method) until the action of the heat decomposed them into gasoline. Such plants are known as *Thermal Cracking* plants.

Meanwhile, the design of internal combustion engines for motor-cars and aeroplanes was progressing, and, size for size, they were becoming more powerful. The arrival of these new, higher-powered engines revealed a curious fact: it was found that the gasoline produced by cracking, which at first had been looked on only as an inferior supplement to the original kind of gasoline distilled straight from petroleum, actually suited the more powerful engines a lot better. A fuller explanation of this must be left until later; for the moment we are concerned with its consequences—which were that the higher quality of 'cracked' gasoline encouraged engine designers to think in terms of yet higher power output, and so in turn to demand still better gasoline from the oil industry. The industry's research scientists had to find a way in which the cracking process could be made to yield still better kinds of gasoline. This problem was finally surmounted by a major innovation in cracking technique—the use of a catalyst.

It was found that certain inorganic salts such as silicates introduced into the cracking reaction vessel acted as a catalyst and enabled the cracking to occur much more easily and at lower temperatures; furthermore, greater control and constancy of results were obtained, and finally, the gasoline obtained was considerably improved in quality. The catalytic action, evidently an unmitigated blessing in every way, would appear to depend on surface effects since it is most marked when the salt is in the form of small beads or fine powder.

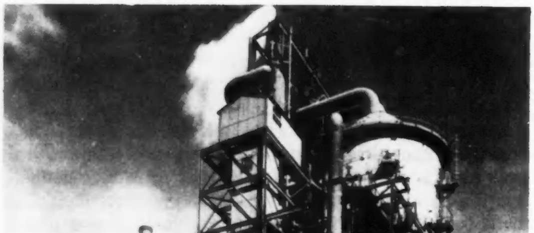
This important discovery led to the development of the new style of cracking process—the Catalytic Cracking plant or 'Cat-Cracker'. The design and construction of these huge plants, now totalling some sixty, has up to now been mainly confined to the U.S.A.; the first one was completed in 1940. They are imposing structures, sometimes over 200 feet in height, and have a characteristic and striking

appearance; most of them are equipped with lifts to take employees to the various platforms.

Output of a cat-cracker can be as high as 35,000 barrels per day. (A barrel equals about 35 imperial gallons.) There is not much to choose, in looks, between one plant in an oil refinery and another—they are mostly a confusion of tanks, pipes, and tall columns. But the cat-cracker is different; it has graceful lines and somehow a personality of its own, one which arouses in those familiar with it the same sort of feelings of affection and pride as does the 'Queen Mary' or the 'Flying Scotsman'.

Catalytic cracking processes are of several different types, including the Houdry, Thermofor, Suspensoid, Cycloversion and Fluid Flow Processes. The last-named is the only one I propose to deal with. Its name refers to the fact that the catalyst is in this case an extremely fine powder—so fine that it possesses almost liquid properties; it can be aerated or 'fluffed up' by a stream of air and in this condition will flow through pipes. Also, even when not 'fluffed up' it will exert a hydrostatic pressure or 'head' as a liquid does.

In all catalytic chemical reactions, once the reaction is completed the catalyst is left chemically and often physically unchanged. The Fluid Flow Cracking Process is no exception and the same catalyst is used over and over again. In spite of this, small losses are inevitable; and even the best of catalysts 'wears out' eventually. Replacements of catalyst are therefore made periodically, and from time to time truckloads of fresh catalyst arrive by rail to be fed into the plant. The rail waggons are of special design, closed and with square hatches in the flat roof, and with pipe outlets for the catalyst in the bottom. These pipe outlets are coupled to the plant's intake pipe, and suction motors draw the powder into the plant. A fresh truckload



A fluid flow cat-cracker at the Dominguez Refinery, California. (*Shell photograph.*)

of catalyst, however, is often found to have become caked hard under its own weight, and has to be loosened before it will flow out into the pipes. This is done by means of a thin metal pipe attached to a supply of compressed air. With the air off, one of the hatches in the roof is opened and the pipe thrust into the caked catalyst to the depth of about a foot. The air is then turned on, and the catalyst becomes fluid.

In most Fluid Flow 'Cat-Crackers' the chief visible feature is a large cylindrical container with a conical top and bottom, which surmounts the whole structure; it is known as the Regenerator. A second cylindrical vessel, longer and rather thinner, is conspicuous usually at a lower level in the plant; this is the Reactor. These two vessels are the key points in the process. As its name suggests, this process is a continuous flow method, in which the input of heavy oil fractions is continuous, the output of gasoline also continuous, and the same catalyst circulates repeatedly round the system. The essentials of the process are the flow of the three principal streams—catalyst, oil and air; and the process can best be explained by following the case-history of the heavy oil and the associated catalyst as they travel through the plant.

Entering the plant from outside, the heavy oil is pumped through preheaters (which, however, do not vaporise it), and then along a feed pipe. This feed pipe is immediately joined by a vertical pipe (the regenerator standpipe) which leads straight down from the regenerator. Down this vertical pipe comes very hot fresh catalyst, at about 1100° F.; as soon as this meets the incoming heavy oil its heat causes the oil to vaporise instantly. The foaming mixture of vaporised heavy oil and catalyst powder now passes along the remainder of the original pipe and up into the reactor.

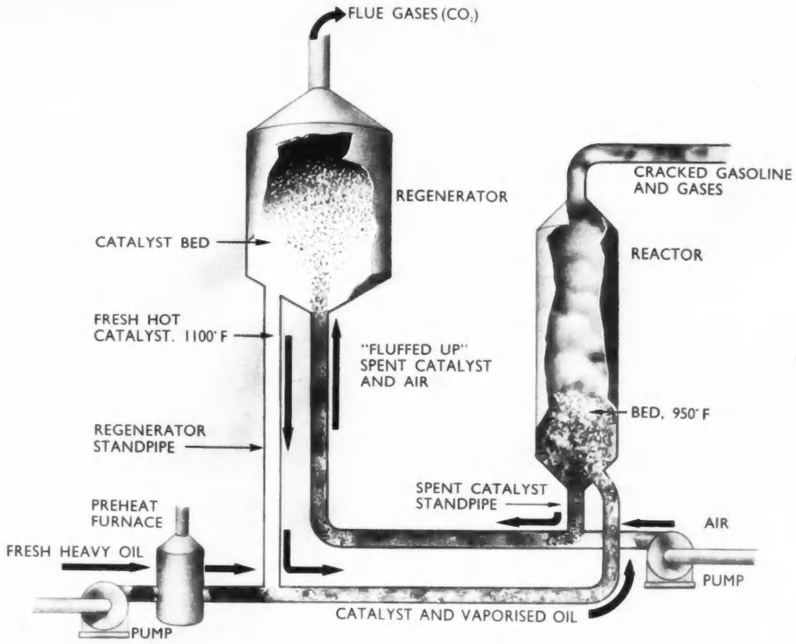
The reactor is the actual reaction vessel in which the cracking occurs. But no external heat is supplied here: what happens is that the catalyst now settles to a definite level in the reactor and forms a 'bed', which is kept in a fluid, turbulent condition by the heavy oil vapours. Continuously passing upward, these vapours obtain intimate contact with the finely powdered hot catalyst, and a uniform temperature of 900–950° F. is maintained throughout the bed.

The pressure, however, is not high, but is in the region of normal atmospheric pressure; for unlike thermal cracking, this is a 'vapour-phase' process. Although the cracking occurs within the actual 'bed', it must be remembered that this bed is mainly a vaporous one, a swirling, heaving mixture composed of oil vapours and red-hot catalyst. Just the kind of bed, in fact, that the Mikado might have chosen for his "humorous and lingering" punishment that involved boiling oil.

The products of cracking rise as vapours to the top of the reactor and pass out through an outlet pipe in the top. These products consist mainly of gasoline, but among them there are also some light volatile hydrocarbon gases; these will be discussed later. These products are then piped away to be separated by ordinary fractional distillation.

One of the products formed during the cracking, however, is coke: this gets deposited on the catalyst particles. Thus the catalyst in the reactor gradually gets covered up and so loses its power. The spent catalyst falls under gravity and passes out of the reactor at the bottom through

THE FLUID FLOW PROCESS



a separate pipe, the 'spent catalyst standpipe'. Lower down in this pipe the spent catalyst meets a stream of air which has been pumped in from outside. This 'fluffs up' the catalyst, reducing its density so that it flows up another pipe, the 'regenerator return pipe' which leads straight up back into the regenerator. In the regenerator, the spent catalyst again settles down to form a bed through which the air passes; the air is thus brought into intimate contact with the still very hot particles of spent catalyst and it burns all the coke off them. This burning brings the catalyst temperature back to 1100° F. The catalyst is thus restored to its fresh working state, or 'regenerated'—hence the name given to this vessel—and is now ready to start a fresh cycle. The carbon dioxide and other 'flue gases' from the burning pass through a centrifugal separator called a cyclone and then through an electrostatic precipitator. Through these two devices any stray catalyst particles in the flue gases are retained in the regenerator.

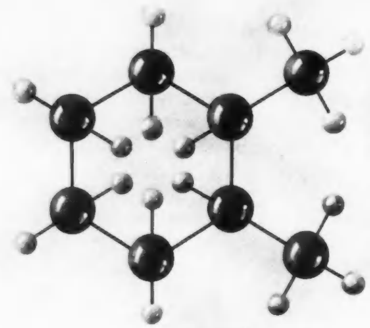
In practice the process is continuous, every part of the plant operating simultaneously, and with a steady flow of the catalyst round the plant. The inherent symmetry of the process about this catalyst circulation will be noticed: on the one side, oil and reactor bed; on the other, air and regenerator bed.

In this simplified description of the Fluid Flow Process it will be noticed that there is no mention of any outside mechanical aid in carrying the oil and catalyst from one part of the process to the next. The first pump merely brings the heavy oil from storage through the preheat furnace to the bottom of the regenerator standpipe. From then on the flow is caused entirely by the hydrostatic pressure or 'head' of the catalyst in the regenerator and regenerator standpipe. This catalyst is in solid, un-aerated form and therefore of much higher density than when it is dispersed among the oil vapours on its way to the reactor. Similarly, the second pump merely brings in air from outside at sufficient speed to 'fluff up' the spent catalyst; again it is the hydrostatic head of this spent catalyst in the reactor and in the pipe *before* it meets the air, which drives the lower-density 'fluffed up' spent catalyst ahead of it and all the way up to the regenerator. The products of cracking, being in vapour form, look after themselves and pass up the reactor and out at the top; the spent catalyst, being heaviest, drifts continuously to the bottom of the bed.

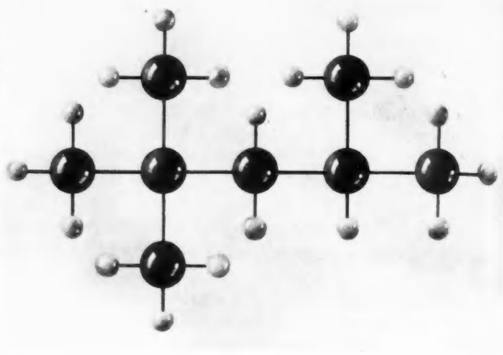
In the Fluid Flow Process we see the combination of many advantages arising from the use of a catalyst; once the plant has been started up the cracking proceeds without any external heat source beyond the small preheat furnace, and at roughly atmospheric pressure. It is, in effect, the heat produced by the burning-off of coke in the regenerator that keeps the process going; this heat is carried by the catalyst to the incoming fresh oil, serving both to vaporise it and later, in the reactor, to crack it.

Thus the Fluid Flow Process is almost completely self-contained and remarkably free of moving parts, a fact that makes for great ease of running, low maintenance and repair work, and extraordinary economy in manpower. Temperatures, pressures and rates of flow are controlled by automatic instruments in a central control room and a very high degree of control is obtained.

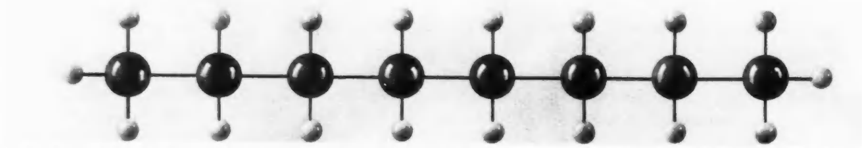
Coupled with this exact control, the Fluid Flow Process possesses great flexibility with respect both to the type of heavy oil fed into the plant and type of output. A flick of the wrist can change any one of a number of variables, such as the catalyst-to-oil ratio, the reactor temperature, etc. One of the most important of these variables is the depth of the reactor bed. This depth regulates the total time taken



(*Left*) Structural model of ring compound typical of cracked gasoline. (1, 2 *dimethylcyclohexane.*)



(*Right*) Typical highly branched molecule from cracked gasoline. (2, 2, 4 *trimethylpentane.*)



Straight chain molecule typical of ordinary distilled gasoline (*n-octane*).

by the cracking reaction; and it can be varied to provide different degrees of cracking, so as to modify the quality of the resulting gasoline and the proportion of gasoline to other products. We must now examine more fully this idea of the *quality* of a gasoline.

I have already mentioned that cracked gasoline in general was found to suit higher-powered engines much better than straight-distilled gasoline. This is because the straight-distilled variety causes *knocking* (often called 'pinking', and also known as 'detonation') in the higher-powered engines, while cracked gasoline does not. Higher power output in engines is obtained by increasing the compression ratio: but with high compression ratios the extra power is lost when running on poor quality gasoline of the straight-distilled type, because of knocking; this does not occur when the engine is running on the better, cracked gasolines. The ability to withstand knocking during combustion is thus a property peculiar to each individual kind of gasoline—a good gasoline, such as is produced by cracking, possesses it to a greater degree than poor gasolines. This quality of a gasoline is called *anti-knock value*; it is measured in terms of what is called *Octane Number*. The higher the Octane Number, the better the gasoline resists knocking; hence the higher the compression-ratio with which it will give smooth running, and hence indirectly the higher the power we can get with an engine of a given capacity.

Knocking is caused by an explosive type of chain-reaction within the engine cylinder; and whilst its exact mechanism is not completely understood, it is known to be intimately bound up with the type of molecular structure of the gasoline, for it depends directly on the amount of 'branching' of the carbon chain. Thus many straight-distilled gasolines contain hydrocarbon molecules whose carbon atoms are joined in a single straight chain, and this type of molecular structure encourages knocking more than any other. The farther a gasoline's molecular structure deviates from this straight chain pattern by 'branching' or by the formation of carbon 'rings', the less it tends to knock, and the higher its Octane Number. Now this is precisely the difference between straight-distilled and cracked gasoline; for in cracking, not only do the large molecules of the heavy oil fractions split up—they also rearrange themselves, producing *branch*-chain molecules and ring-molecules of the good-gasoline type. This, then, explains the better quality and higher Octane Number of cracked gasoline.

An average straight-distilled gasoline might have an Octane Number of, say, 45 to 55; when thermal cracking was introduced the figure was raised to between 60 and 70, while catalytic cracking pushed it up to about 82. ('Pool' petrol in Britain during the war was fixed at 70 Octane.)

The particular significance of adjusting the level of the reactor bed in the Fluid Flow Process can now be appreciated: for this depth controls the relative amounts of molecules of different degrees of 'branch-chaininess' in the final gasoline and so the Octane Number of the final product in relation to its quantity can be varied according to the market demand of the moment. During the war, for instance, vast quantities of extremely high-octane aviation spirit were urgently needed for the Allied Air Forces, and 'cat-crackers' were pressed into service and worked to capacity both as to quantity and Octane Number.

But the high-powered engines of combat aircraft demanded considerably higher Octane Numbers than the 82 or so of catalytically cracked gasoline. Here again, however, catalytic cracking supplied the answer—this time in the light, volatile hydrocarbon *gases* produced alongside the gasoline as a result of the cracking. These could be polymerised or joined together in other ways to form even higher concentrations of highly branched molecules in the form of 'high-octane blending agents'.

These light hydrocarbon gases find yet another highly important outlet; for they are chemically highly 'reactive', and because of this they can be used as building bricks for the synthesis of many different and complex molecules. Thus in the last 15 years a great chemical industry has grown up depending on these 'cracked gases'; solvents, plastics, synthetic rubber and glycerine are a few of the important products. Great Britain's own new chemical industry based on petroleum, has recently been launched, and several 'cat-crackers' are scheduled for building in Britain, to provide both the gases for new chemicals and more and better gasoline for the motorist.

(*The drawings for this article were prepared by Francis Rodker.*)

Old and New Titanium

M. SCHOFIELD, M.A., B.Sc., F.R.I.C.

THE metal titanium, a pure form of which Wöhler and Deville struggled to prepare just a century ago, is once again coming into prominence as a result of considerable research now going on. For some years this element, classified in Group IV of the Periodic Table and rather suggesting silicon in its affinity for oxygen and the insolubility of its oxide, has proved a hard-working and versatile member of Chemistry House, new uses being found for it when old applications were declining. Titanium in the form of the alloy with iron is not used so extensively for removing oxygen and nitrogen in steel-making as it was, but to compensate for this, titanium won new favour in the manufacture of extra-hard cutting steels and in making high-strength aluminium alloys. Titanium oxide is a highly prized raw material in the paint industry, a superior non-toxic pigment of high opacity and whiteness. Its carbide is used in the manufacture of cutting-tools, there is a demand for titanium salts in dyeing and laundering, and titanium chloride (which is a fuming liquid) enables the element literally to write its name across the sky in the once so fashionable method of advertising called sky-writing.

New sources of titanium seem to be keeping pace with new demands. In the Allard Lake area of Quebec what are claimed to be the world's richest deposits of ilmenite (estimated at 150 million tons) are now attracting attention, and promise to place Quebec in the premier position regarding the world's titanium supplies.

Titanium has been called a 'rare' metal only because of the difficulty in extracting it from ores. Actually it stands eighth in the list of elements arranged in their order of natural abundance. Titanium seems at first something of a paradox, being so rarely known outside chemistry and metallurgy although it is contained in widely distributed minerals.

Sources of Titanium

Ilmenite, a form of ferrous titanate, has been produced up to now at the rate of 250,000 tons a year (though the working of the new Quebec deposits may easily quadruple this). It is a black mineral from which titanium oxide, the finest white pigment known, is derived. The other main ore of titanium is rutile, a mineral which ranges in colour from reddish-brown to violet. This is nearly pure titanium oxide, since the dressed ore contains up to 98% titanium oxide. Half a century ago Norway produced 100 tons of rutile a year and this represented the whole of industrial titanium. Though rutile is widely distributed, the emphasis today is on ilmenite, which contains 45 to 55% titanium oxide; the content varies according to whether the mineral comes from Norway, Australia, the beach sands of Travancore, or from Malaya where it is separated from tin ore.

Travancore sands form a particularly interesting source of ilmenite. For they contain also zircon or zirconium silicate, together with 5% of monazite composed of phosphates of such rare earth metals as cerium, thorium, lanthanum and praseodymium. In addition to rutile and ilmenite, the output of which soared from 600 to 250,000 tons within twelve years, 'sphene' or silicate of titanium and calcium is reported to be exploited in Russia.

A strong British interest in titanium goes back beyond the first industrial application of a titanium compound. For it was in Cornwall that titanium first came to light. This county saw the Rev. William Gregor turn his analytical skill to a black magnetic sand found in his parish. This sand, which looked like gunpowder and is now known to be ilmenite, yielded 46·6% magnetite, 3·5% silica, and 45% of 'reddish brown calx', this latter dissolving in acids to a yellow solution turning purple with reducing agents. Gregor realised that a new element had turned up; and he named it Menachanite, predicting that one day chemists would "rob it of its novelty". But in naming it he had reckoned without the eminent German analyst, Klaproth, author of a six-volume classic of mineral analysis. Klaproth took what is now known as rutile, and analysed it long after Gregor's discovery had been forgotten. Although he acknowledged the identity of his new element with 'menachanite', he proceeded to baptise it in the Klaproth manner: "I shall borrow the name for this metallic substance from mythology, in particular from the Titans, first sons of the earth. I therefore call this new metallic genus *Titanium*."

The Hunt for the Pure Metal

A number of eminent chemists were attracted to the problem of preparing free titanium, the stumbling-block ever being the element's exceptional affinity for nitrogen as well as oxygen, an affinity put to good use when ferro-titanium is used for 'scavenging' (that is, removing gaseous impurities from steel. Wollaston was early in the hunt; but the hard cubes he produced from a furnace slag proved to be titanium nitride mixed with carbon. Berzelius worked on a double fluoride of potassium and titanium. This on heating with potassium metal yielded a black powder which, however, was far from being the pure element. In 1849, Wöhler and Deville carried out a similar experiment using a hydrogen atmosphere and produced a grey powder of metallic appearance. Moisson, in 1895, attempting to reduce the oxide with carbon, obtained a metallic product containing about 2% of carbon. In 1910, Hunter, improving on similar work by Nilson and Pettersson, produced metal of high purity (said to be 99·9% pure) by reducing liquid titanium tetrachloride with sodium in a steel bomb.

The first method, however, which was adapted to relatively large-scale production of good-quality metal, was due to Kroll and consists of reducing the tetrachloride with molten magnesium. This process has received considerable application in America. Titanium chloride is fed into molten magnesium above which an argon or helium atmosphere is maintained, the temperature being kept between 800° and 900°C. A rotary delivery-pipe sprays the titanium chloride over a large area of magnesium to prevent the magnesium vapour boiling up the feed-pipe with the heat of the reaction; at the same time mechanical breakers deal

with the titanium crust forming on top (since titanium is solid at the temperature of the reaction).

The product of this 'magnesium-reduction' process is a metal powder or sponge, which is then converted to a useful solid form either by melting or by the method of powder metallurgy.

The purest form of titanium is now produced by what is known as the 'iodide process'. This involves the reaction, in vacuum, of iodine vapour with impure metal to form gaseous titanium iodides. These iodides are decomposed when they come into contact with an electrically heated tungsten or titanium filament in the same reaction vessel. A rod of titanium of very high purity is thus built up on the filament. In America, 700 gram rods are now being produced by this method.

Titanium for many years has been used in the impure, alloyed or compound state, and has played an important but unobtrusive part. Why all the present interest and research on titanium? Mainly because the inherent properties of titanium itself have but recently been determined and the results indicate that the metal is superior to many established metals and alloys in use today. At its present price, however, titanium could only be used for special purposes and where cost is not an over-riding factor. If, as many people believe, the present intensive research results in a much cheaper extraction process, there would open up a very wide field of application.

Titanium looks like polished steel yet has only half the density. It is proof against corrosion by most acids, industrial fumes, and by sea-water. For some time titanium has been a luxury as free metal for use as a 'getter' in removing traces of gases in vacuum tubes. It has gone into non-ferrous alloys, particularly of aluminium, into chrome-nickel stainless steels, and, as if in support of old Klaproth's 'Titanic' name, into armour-plate for naval construction. New shock-resisting titanium and tungsten carbide materials, for valve-seats, die-inserts and nozzles, together with such alloys as Konel (composed of iron, nickel, titanium and cobalt), alloys which are noted for their exceptional heat resistance, represent further advances.

The 'iodide titanium' is the purest produced in any quantity; it contains up to 0·03% carbon and 0·003% nitrogen, and is soft and ductile. The so-called 'commercially pure titanium' produced by firms like the Remington Arms Company, contains about 0·3% carbon and a few tenths of one per cent of gaseous impurities. For many purposes titanium of 'commercial' grade, with up to 2% total impurities, will serve. There is a big range of properties available according to the purity of the metal; thus it may be as soft as copper or as hard as constructional steel.

N. E. Promisel of the U.S. Bureau of Aeronautics has predicted the value of titanium in aircraft as follows: firstly, in place of aluminium and magnesium components because of the superior strength-weight ratio; next as substitute for stainless steel and resistant alloys by virtue of the exceptional resistance to corrosion by sea-water, particularly in leading edges for high-speed aircraft which normally undergo surface roughening. He also sees titanium applied in lightweight pumping equipment for salt water and for parts adjacent to jets reaching a temperature of 150° to 200° C. (at which the usual high-strength light alloys begin to weaken). This reference to temperature brings up one point not sufficiently stressed in the American studies of titanium and its applications. Below 600° C. embrittlement of the metal by reaction with nitrogen and oxygen traces is not serious; above that temperature it becomes of importance—hence titanium cannot be used in the reaction chambers of gas turbines, for example. However, it is not considered improbable that titanium containing some suitable alloying addition will find use at temperatures in excess of 600° C. The exact effects of traces of oxygen, nitrogen and hydrogen on titanium have still to be determined and interpreted for everyday use.

No account of titanium developments can be balanced unless mention is made of applications of titanium compounds. In contrast to odd uses like titanium chloride in smoke bombs, smoke screens, and in 'sky-writing' the two applications of titanium oxide in the paint industry and of titanium-reducing agents in textiles are of high importance. Titanium oxide has a chemical stability, inertness, whiteness and non-toxic property which makes it an ideal white pigment for paints, enamels, plastics and cosmetics. In paints its covering power is so high as to offset its rather high cost. In association with barium or calcium sulphate, titanium oxide with its complete lack of toxic properties (compared with white lead) finds wide application in paints for food factories and equipment, for dairies, hospitals and nurseries. The second striking use of titanium compounds recalls the use of titanous sulphate solution in the laboratory for volumetric estimations. In dyeing and colour-printing titanous salts prove invaluable because of their 'reducing' effect. In dyeing leathers the manner in which workers refer to 'T.P.O.' (titanium potassium oxalate) illustrates the extent to which it finds everyday use in that industry.

The Cornish parson Gregor would indeed be surprised if he could see his 'menachanite' today, an element which he believed chemists would 'rob it of its novelty'.

TWINKLING STARS

Twinkling of stars is usually put down to small local variations in the earth's atmosphere; and its reduction with a telescope to the fact that viewing is through a thicker 'pipe' of air, so that the smaller of these variations are more likely to cancel out.

Two years ago, it was suggested by Prof. H. Hartridge, Director of the Vision Research Unit at the London Institute of Ophthalmology, that the cause of twinkling might be in the eye. He pointed out that the light-sensitive receptors in the central area of the retina are cones which differ in the colours to which they respond, and presumably also in their sensitivity to brightness. For this reason, a slight change in the position of the image formed by the star could lead to changes in its apparent brightness or colour, or both at once. Now, with Dr. R. Weale, also of the Vision Research Unit, he has described in *Nature* some supporting experiments. Hartridge's theory has, however, been received with very great scepticism.

Far and Near

Bernal and the B.A.: A Protest

A STATEMENT deploring the decision of the British Association not to re-elect Prof. J. D. Bernal to its Council (see DISCOVERY, December 1949, p. 396), has received the support of 244 scientists working in university and industrial laboratories and has been forwarded to the British Association. The statement reads as follows: "We deplore the action of the Council of the British Association in depriving itself of the services of Professor Bernal for expressions of his political attitude—expressions with which many of the signatories disagree. The aim of the British Association is the advancement of science. To the furtherance of that aim Professor Bernal has made signal contribution."

The sponsors of the statement include the following: Prof. Gordon Childe, Dr. Dorothy Crowfoot-Hodgkin, Prof. J. B. S. Haldane, Prof. Kathleen Lonsdale, Dr. Joseph Needham, Dr. Dorothy Needham, Prof. L. S. Penrose, N. W. Pirie, Dr. W. A. Wooster and Dr. F. Yates.

Other signatories to the statement include: Professors P. A. M. Dirac, P. G. 'Espinasse, M. Gluckman, F. G. Gregory, L. Hawkes, H. Levy, C. F. Powell, S. Tolansky and J. H. C. Whitehead.

Antibiotic Research at Sefton Park

A NEW research unit which will be wholly concerned in finding and developing new antibiotics is being installed by Glaxo Laboratories in a large mansion at Sefton Park, near Stoke Poges, Bucks.

1950 Linnean Medal

THE Linnean Medal, the highest honour the Linnean Society of London can bestow, is awarded this year to MR. HENRY N. RIDLEY, who was for many years director of the botanic gardens of the Straits Settlement. He was closely connected with the establishment of the early rubber plantations in Malaya; indeed *Who's Who* credits him with founding the industry in 1895. He wrote a 5-volume Flora of the Malay Peninsula and published in 1930 the valuable monograph *The Dispersal of Plants*. Mr. Ridley is in his 95th year.

Special Promotion for Government Scientists

SPECIAL promotion for scientists of exceptional merit was recommended in the now historic White Paper on the Scientific Civil Service, issued in 1945. This year under this scheme two scientists have been upgraded to the rank of deputy chief scientific officer, which is broadly equivalent to a professorship in the academic world. The two scientists thus promoted are DR. R. A. FRAZER, F.R.S., of the National Physical Laboratory, an authority on aircraft flutter, and MR. S. B. GATES, F.R.S., an expert on aerodynamics with the Ministry of Supply.

£8½ million on Naval Research

PARLIAMENT has approved the estimate of £8,697,000 to cover the cost of the Navy's scientific services during the next year. This figure includes the grant-in-air to the National Institute of Oceanography.

The Ministry of Defence Estimates for 1950–51 include an item of £38,044 for a new directorate—the Directorate of Scientific Intelligence.

A New Asteroid

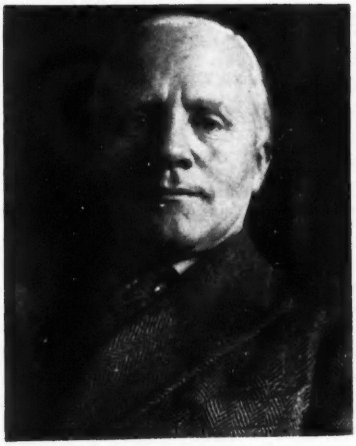
THE New York correspondent of *The Times* reports that a heavenly body discovered by astronomers in California has been identified by Harvard observatory as an asteroid and given the name temporarily of '1950 A.D.' He quotes Dr. Harlow Shapley as saying that it was unusual, for there are "only about a half-dozen of its type that enter the earth's orbit among the 1000 known asteroids". It is believed to be about two miles in diameter, and it was approximately 5 million miles from the earth at its nearest approach, on March 13.

Isotopes in Industry

A CONFERENCE on 'Isotopes in Industry' is being held from May 19 to May 21, at the University, Birmingham. The Conference is designed to introduce radioactive isotopes and the associated techniques to industrial scientists and technologists. Further details may be obtained from the Department of Extra Mural Studies, University of Birmingham, Edmund Street, Birmingham, 3. Telephone, Central 8541, extension 12.

Scientific Films at the Science Museum

SCIENTIFIC film shows are being held on the third Saturday of every month in the Lecture Theatre of the Science Museum at South Kensington. These shows have been arranged by the Scientific Film Association and will take place at 10.45 a.m. Admission is free.



Prof. G. R. de Beer, new director of the National History Museum.

New Atomic Station

THE Government is building a sixth atomic energy establishment, at Aldermaston, fifteen miles from Harwell.

The Night Sky in May

The Moon.—Full moon occurs on May 2d 05h 19m, U.T., and new moon on May 17d 00h 54m. The following conjunctions with the moon take place:

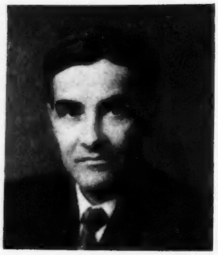
May			
10d 04h	Jupiter in conjunction with the moon	Jupiter	2° N.
13d 02h	Venus	Venus	2° S.
25d 15h	Saturn	Saturn	0.1° N.
26d 12h	Mars	Mars	0.2° N.

The Planets.—Mercury is an evening star in the early part of the month but is too close to the sun to be seen favourably; later it becomes a morning star but as it rises only 25 minutes before the sun on May 31 it is not visible. Venus is a morning star, rising more than an hour before sunrise throughout the month, but it is not visible for long as it is lost in the twilight. On May 13 the planet is close to the moon in the early morning hours, as pointed out under conjunctions. Mars is visible throughout the night in the constellation of Leo. Notice that its westerly movement amongst the stars in the early part of the month is almost imperceptible and on May 5 it is stationary, after which it moves eastward and towards the end of the month it is close to the star β Virginis. The brightness of Mars diminishes during May as its distance from us increases from 66 to 89 million miles between May 1 and 31. Jupiter rises nearly 2 hours before the sun on May 1 and 3 hours before the sun on May 31 and can be seen in the morning hours in the constellation of Aquarius but is too low for favourable observation. Saturn is a little north of Mars and sets about the same time in the morning hours; a small telescope shows the ring which is opening up; although its plane is directed nearly towards the earth it is a beautiful sight and will become more conspicuous during the year.

Reference has already been made to the constellation of Virgo into which Mars moves during the month and conspicuous amongst its stars is α generally known as Spica. If there is any doubt about its identity you can find it by drawing a line through α and γ Urs. Maj., that is through the first and third stars of the Plough; this line prolonged passes close to Spica. At the beginning of May it is south at 10.45 p.m. and two hours earlier on May 31. Spica is a double star but its companion cannot be seen with a telescope as it is too close to Spica—only about 6¼ million miles distant, and each star revolves around the common centre of gravity of the system in 4 days. Double stars are very common, probably half the stars being double, but many are too close to be seen as double stars even with the aid of large telescopes.


DR. BABKIN

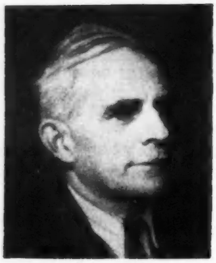

PROF. BATES


PROF. BENNET-CLARK


DR. BLEANEY


DR. COMRIE


DR. COX


S. B. GATES


PROF. JONES


PROF. MORTON


COLONEL SHORTT


DR. SUTTON


R. L. M. SYNGE


DR. UVAROV

New F.R.S.s


PROF. WILLIAMS

The Royal Society's New Fellows

THE Royal Society has elected the following 25 new Fellows:

DR. B. P. BABKIN, physiologist of McGill University, Montreal.

PROF. F. L. BATES, Department of Physics, University of Nottingham; an authority on ferromagnetic substances.

PROF. T. A. BENNET-CLARK, Department of Botany, King's College, London; plant physiologist.

DR. B. BLEANEY, Lecturer in Physics, Oxford University; experimental physicist specialising in microwave spectroscopy and low-temperature physics.

DR. L. J. COMRIE, Director, Scientific Computing Service, London.

PROF. C. A. COULSON, Professor of Theoretical Physics, King's College, London; distinguished for his application of quantum theory to chemical problems.

DR. L. R. COX, Department of Geology, Natural History Museum; invertebrate palaeontologist.

PROF. H. S. COXETER, Professor of Mathematics, University of Toronto.

DR. G. H. CUNNINGHAM, Director, Plant Diseases Division, New Zealand Department of Scientific and Industrial Research; expert on rust fungi.

DR. W. J. ELFORD, biophysicist at the National Institute for Medical Research, London; distinguished especially for his research on methods of determining virus size.

S. B. GATES, Senior Principal Scientific Officer, Ministry of Supply (Air); a pioneer in the scientific study of the dynamics of aircraft.

DR. C. A. HOARE; protozoologist to the Wellcome Laboratories of Tropical Medicine, London; an authority on trypanosomes.

PROF. L. HOWARTH, Professor of Applied Mathematics, University of Bristol.

PROF. E. R. H. JONES, Professor of Organic Chemistry, University of Manchester; an authority on steroids, carotenoids and the chemistry of acetylene.

DR. A. J. P. MARTIN; biochemist at the National Institute for Medical Research, London; developed partition chromatographic methods of chemical analysis.

DR. D. F. MARTYN, Principal Scientific Officer at the Solar Observatory, Canberra; distinguished for his contribution to various aspects of scientific radio, including ionospheric variations.

PROF. R. A. MORTON, Professor of Biochemistry, University of Liverpool; authority on fat-soluble vitamins.

PROF. R. J. PUMPHREY, Professor of Zoology, University of Liverpool; distinguished for research on the sense organs and central nervous system of animals.

DR. A. G. SHENSTONE, Professor of Physics, Princeton University, formerly Scientific Liaison Officer in London of the

Canadian National Research Council; an authority on spectroscopy.

COL. H. E. SHORTT, Director of the Department of Parasitology, London School of Hygiene and Tropical Medicine; distinguished for his work on protozoal diseases; recently discovered new phase in the life history of malarial parasite.

PROF. M. STACEY, Professor of Chemistry, University of Birmingham; organic chemist, well known for his studies of the carbohydrates of animal tissue and of micro-organisms.

DR. L. E. SUTTON, Lecturer in Physical Chemistry, Oxford University; distinguished for work on the electrical properties of molecules.

R. L. M. SYNGE, Rowett Research Institute; responsible for the application of partition chromatography to the separation of amino-acids and peptides.

DR. B. P. UVAROV, Anti-Locust Research Centre, Natural History Museum, London; an authority on the Orthoptera and famous for the part he has played in organising international measures for the control of locusts.

PROF. F. C. WILLIAMS, Professor of Electro-Technics, University of Manchester; distinguished for his work on radar and the development of electrical computing machines.

Elements 97 and 98

THE discovery of a new element, No. 97 in the Periodic Table, was announced in January. It was found by Dr. Glenn T. Seaborg and his associates to be produced when americium (element No. 95) is bombarded with alpha particles. The discovery was made at the University of California and was first announced by a daily paper. After the 'leakage' the University and the U.S. Atomic Energy Commission issued a statement which said that "after four years' work in which the necessary background information of both the chemical and nuclear properties of the heavy elements (were) investigated and systematised . . . extremely small amounts of the new element were made on the 60-inch cyclotron of the Crocker Radiation Laboratory. . . . Details concerning how the new isotope was made and its properties are not available, but theoretical considerations rule out its use in production of atomic weapons. It is proposed to call the new element 'berkelium'.

Seaborg's group has since discovered element No. 98. This is produced when alpha particles hit nuclei of curium (element No. 96, which was synthesised by Seaborg and his associates in 1945). Element No. 98 has been named 'californium'.

Obituaries

THE death occurred at Birmingham on March 18 of SIR NORMAN HAWORTH, F.R.S., aged 66, for many years Professor of Chemistry at Birmingham University. His researches on carbohydrate chemistry and vitamin won him a Nobel Prize for Chemistry in 1937.

FREDERICK TWORT, F.R.S., M.R.C.S., died on March 20, aged 72. He was famous for his discovery in 1915 of the bacteriophage (the filtrable virus which parasitises certain kinds of bacteria and can cause their dissolution).

The Physical Society Exhibition

THE 34th Physical Society Exhibition held this year at Imperial College provided once again opportunities for scientists and interested laymen to see for themselves the instruments now available. Altogether some 107 firms exhibited, a change indeed from the eleven that put up their stands at the first exhibition in 1905. Visitors were able to see the present efficiency of the instrument-making trade, which began a little hesitantly about two centuries ago. In fact, one firm—Elliott Brothers (London) Ltd., founded in 1800—this year showed one or two of the first instruments they made. This year's stupefying array of bright and shining instruments demonstrated by smart electronic experts would, one imagines, have astonished a man like Faraday and made him hide his own electromagnetic apparatus in shame.

By paying close attention to what was being shown, the visitor to this year's show could eliminate a lot of the gadgetry and find here and there something to remember. There were some demonstrations of a relatively simple sort that had been well thought out. Marconi's Wireless Telegraph Co., for example, now celebrating its jubilee, worked a model to demonstrate the changes in field strength of the ground ray of a wireless signal as it passes from land to sea. The terrain was simulated by sheets of Paxolin sprayed on one side with zinc. With the metal side up, the conductivity is high, analogous to that of sea water for short wireless waves; with the metal side underneath, the material has a resistance analogous to that of land. Waves 3 centimetres long were emitted from a funnelled waveguide and the signal was received on a similar waveguide acting as receiving aerial and then amplified and applied to a recording instrument. The receiving aerial could be moved in a straight line towards and away from the transmitting waveguide. It could also be raised to show roughly the change in field strength with height above land or sea level. With this apparatus it was shown that the field strength of earth-conducted wireless waves suddenly increases as it passes from land to sea. At the same time the vertical distribution of field strength is changed so that there is no increase with height over the sea, whereas there is over the land. Thus aerial height (as distinct from size) is unimportant over the sea whereas over the land it is of great importance, as all amateur radio enthusiasts know.

Baldwin Instrument Co. has a number of instruments for use in modern factories and research laboratories where radioactivity exists. The ability of β-rays (high-speed electrons) to penetrate thin layers of material is utilised in a thickness gauge. The specimen is held between a source of β-rays (actually radio-thallium) and an ionisation chamber; the result is registered on an instrument dial. Any variation in thickness of a continuous strip during production can thus be seen and corrected. The same company's Statigun is an ingeniously simple device for detecting electric charges accumulating on sheets of plastic, rubber, paper, etc. in the process of manufacture, charges often dangerously high.

Protection for nuclear research workers and those who encounter X-rays is, of course, very important. One instrument displayed was for the workers' routine use. All he has to do is to put the detector in his pocket. At the end of the day he inserts it in an instrument and the dosage to which he has been subjected is immediately shown on a dial in milliroentgens. The detector itself is a tiny condenser built to hold its charge for a number of hours. Any radiation that can cause ionisation of the air discharges the condenser partially or wholly. It is this loss of charge that the instrument measures, though the dial is calibrated to read dosage. There is an increased interest in unusual materials. Murex Ltd. is now producing tantalum for the first time in this country, and this metal is in demand in chemical apparatus and in thermionic valves. The N.P.L. Physics division had a neat demonstration of the heat-conducting properties of gallium, which has great differences of conductivity in the three crystal-axis directions. So if a little solid carbon dioxide is blown on the surface of a flat single crystal, the unequal conductivity along the two axes available in the flat surface makes the ice take the form of an ellipse, the ratio of major to minor axis being the ratio of heat conductivity. The D.S.I.R. Chemical Research Laboratory near by had a demonstration of new molecular models on the Stuart pattern, different from the rod and sphere models with which many people are familiar. The atomic or group models are made in coloured catalin, which can be machined easily. The pegs are of hard rubber. The scale is about one centimetre to an Angstrom unit (10^{-8} cm.). Jigs for machining the units have been devised whereby the most complicated atom unit, carbon with three facets, can be made in $6\frac{1}{2}$ minutes.

Probably the most popular apparatus in the exhibition was the Strobotuner now being developed by Dawe Instruments Ltd. This is a device for tuning musical instruments without depending on hearing. In fact a stone-deaf person could tune an instrument with it. The note sounded is picked up by a microphone and amplified and then made to operate a neon discharge tube. This tube is behind a plate with twelve holes marked with the semitones of a scale. An electrically maintained tuning fork energises a synchronous motor which is geared to twelve wheels rotating at speeds corresponding to the twelve semitones. A stroboscopic disk with radial markings is fixed to each wheel, the number of radii on each being the correct one for the frequency of the note marked on the appropriate hole. The tuning fork can be loaded to indicate plus or minus half a semitone. When a note is sounded the loading is adjusted until the correct set of radii appears stationary. Then the indicator on the loading lever shows how far the note is out of true and the pipe or bar or string can be adjusted accordingly.

The Bookshelf

The Story of Steel. By Max Davies. (London, Burke Publishing Co., 1950; pp. 96, 7*s.* 6*d.*)

THIS book, by a former editor of *Iron and Steel*, is one of the *Commodity* series which includes *The Story of Coal*, and *The Story of Oil.* The author traces the history of the manufacture of iron and steel from the earliest times until today. The book is really in two parts: the first tells a narrative story in historical sequence; the second is an exposition of processes in the steel industry of our own period. This division necessarily involves a certain amount of repetition, because the first half cannot be achieved without some exposition of processes as they were discovered. The present reviewer found the absence of an index a defect, though this might not be taken as such by many readers. It is also a pity that no explanation is given of the contribution made by 'pure' science such as metallography and X-ray crystallography.

Those are the only criticisms I have to offer. The narrative is excellent and the ample illustrations first class, from the dramatic frontispiece—a blast-furnace—to the expository pictures of testing machines in the last pages. A really attractive feature is the author's integrity in his careful use of references and acknowledgment of sources—a feature lacking in many popular books. Nor must the research involved be ignored, as it easily might be, because of the absence of signposts in the form of footnotes; there are facts here that cannot be found in the usual reference books. Even statistics lend themselves to the author's dramatic purpose.

A necessary book for every intelligent layman's (and every politician's!) bookshelf, and the reference library of the modern school. C. L. BOLTZ.

Report on the Chemical Industry 1949. (Association of British Chemical Manufacturers; pp. 76, 5*s.*)

THE chemical industry of this country has a record of achievement which will stand comparison with any industry here or its counterpart in any other country. It heads the list for funds devoted to research, the rate of increase of exports, the rate of re-equipment and many other things. It fails only in making its case popularly known. To the common man chemistry is a mystery which is not revealed by its aloof servants. (A simple way of demonstrating that chemists are unknown to the public is to ask any passer-by to describe one; the answer is—a pharmacist!)

The pre-election proposal to nationalise the chemical industry made it necessary for a statement on present conditions to be prepared. At the invitation of the President of the Board of Trade, the industry's own trade association undertook this. The result is disappointing. The romance of a great, pioneering, scientific industry has received a flat apologia; somebody has rivalled that character of Aldous Huxley's who had the gift of inverted alchemy, and could change the purest gold into lead.

The Association has produced for reference a good deal of material which has not been brought together before, but all the flavour is knocked out of this collection of gross statistics. The report would be of far more use if it gave the names of companies sponsoring new plant, expanding old lines and rounding off monopolies. The American journal *Chemical Engineering* does this every year in a readable and informative way. If the British chemical industry wishes to make a case against nationalisation which will command public support it needs to try again with the help of a journalist from *The Economist* or one of I. C. I.'s advertisement copywriters.

The Delphinium. By Frank Bishop. (Collins Flower Monographs, London, 1949; pp. 144, 9 plates in colour, 12 pp. of black and white photographs, 10*s.* 6*d.*)

The Dianthus. By Will Ingwersen. (Collins Flower Monographs, London, 1949; pp. 128, 11 plates in colour, 12 pp. of black and white photographs, 10*s.* 6*d.*)

IT is rarely that a book dealing exclusively with one particular species of flower is produced; when we get two of a new series of such books we should be grateful. Both are calculated to appeal to readers with a scientific interest in flowers, and their cultivation and breeding.

In *The Delphinium* there is all the information that one needs to grow fine specimens of this delightful flower.

There is a very detailed account of the many species, the many varieties and their origins. There is a special section on hybridising, which gives sufficient information to enable anyone to start tackling the tricky job of breeding new varieties. The colour photographs are extremely good.

The book on *The Dianthus* by Will Ingwersen follows the same plan as that on *The Delphinium.*

These two monographs are well worth a place in the library of any keen gardener.

Soviet Genetics. By Julian Huxley. (London, Chatto & Windus, 1949, pp. 245, 8*s.* 6*d.*)

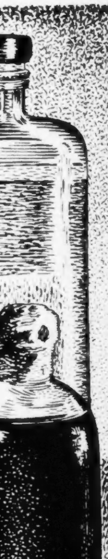
WHILST the argument is developed to a greater extent, and at a higher level, Huxley's thesis in this book is very similar to that of Langdon-Davies in *Russia Puts the Clock Back*, reviewed here last October. The tone and the documentation of Huxley's book will probably make it the more acceptable to scientists, but for the non-expert it will prove to be much harder going. The author is lucid enough, but the wealth of his allusions is likely to stand in the way of the uninstructed layman.

For the biologist this book will prove valuable because of the greater consideration which Huxley gives to the experimental evidence that is sometimes put forward in support of the Lysenko and Michurin point of view. In Chapter Three it is made clear how loose and diffuse are the descriptions of these experiments, and how the absence of adequate controls allows more than one explanation of the results claimed.

There is a useful three-page bibliography of the literature in English that the controversy had given rise to by 1949. Those who seek for a fuller exposition of the present state of development of neo-Mendelian genetics with respect to non-nuclear inheritance and to apparent effects of the environment upon inheritance should read this book in conjunction with Darlington and Mather's *Elements of Genetics.* M. H. C.

Printed and Published in Great Britain by Jarrold & Sons, Ltd., Norwich. *Editorial Offices: 244 High Holborn, W.C.1.*

n on the
and the
, such as
mmonium
group of
proflavine
from the
bility of so
wes much
production
orkers of



ICI

Mo
No
Scie
S
Cal
The
'Fe
t
Vir
Ins
KE
Fis
D.
Ele
Org
C.
Tec
Ass
Pro
RA
Rad
Sev
Pre
of
for
Boo
Far